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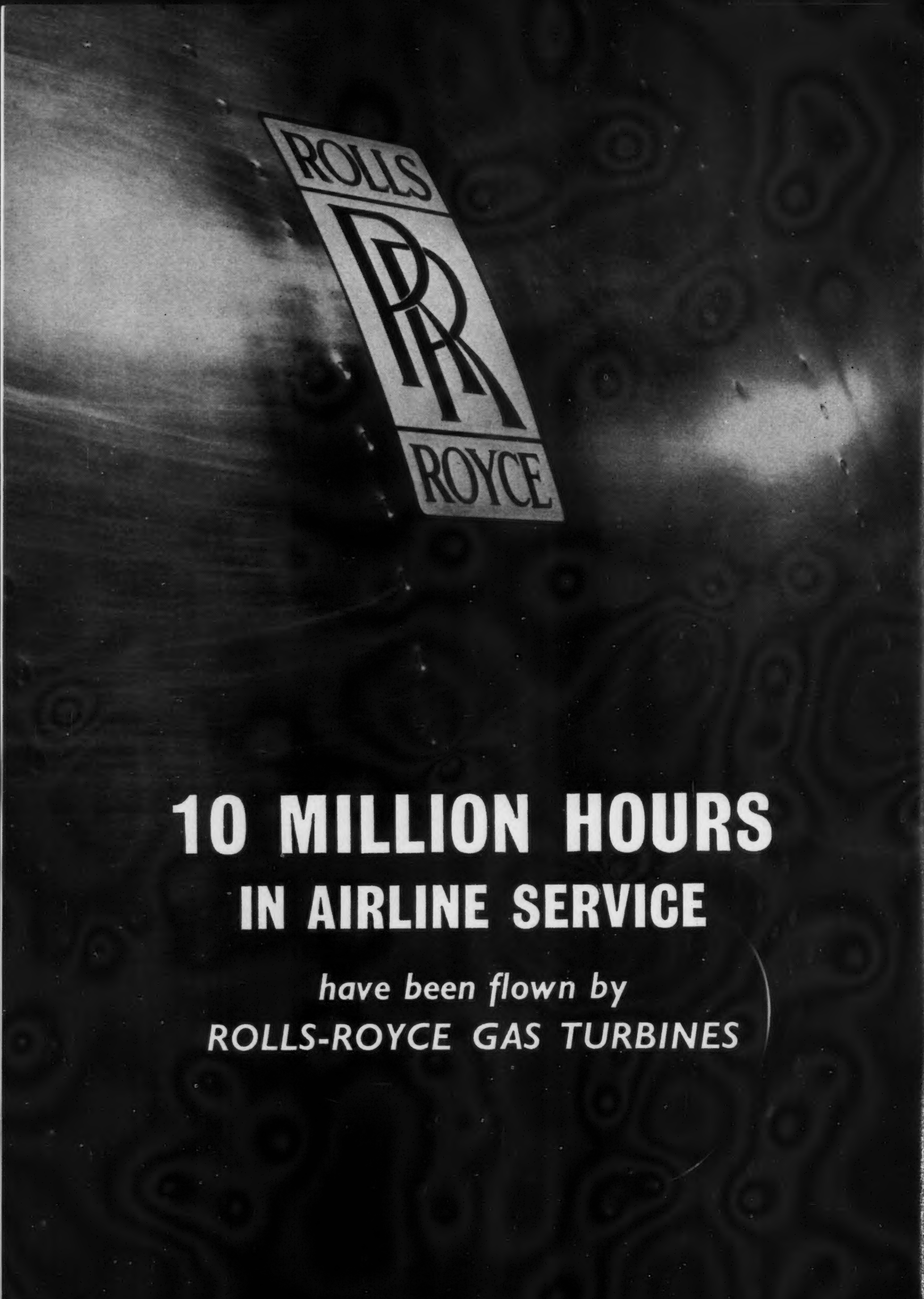
CANADAIR FORTY FOUR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10 MILLION HOURS
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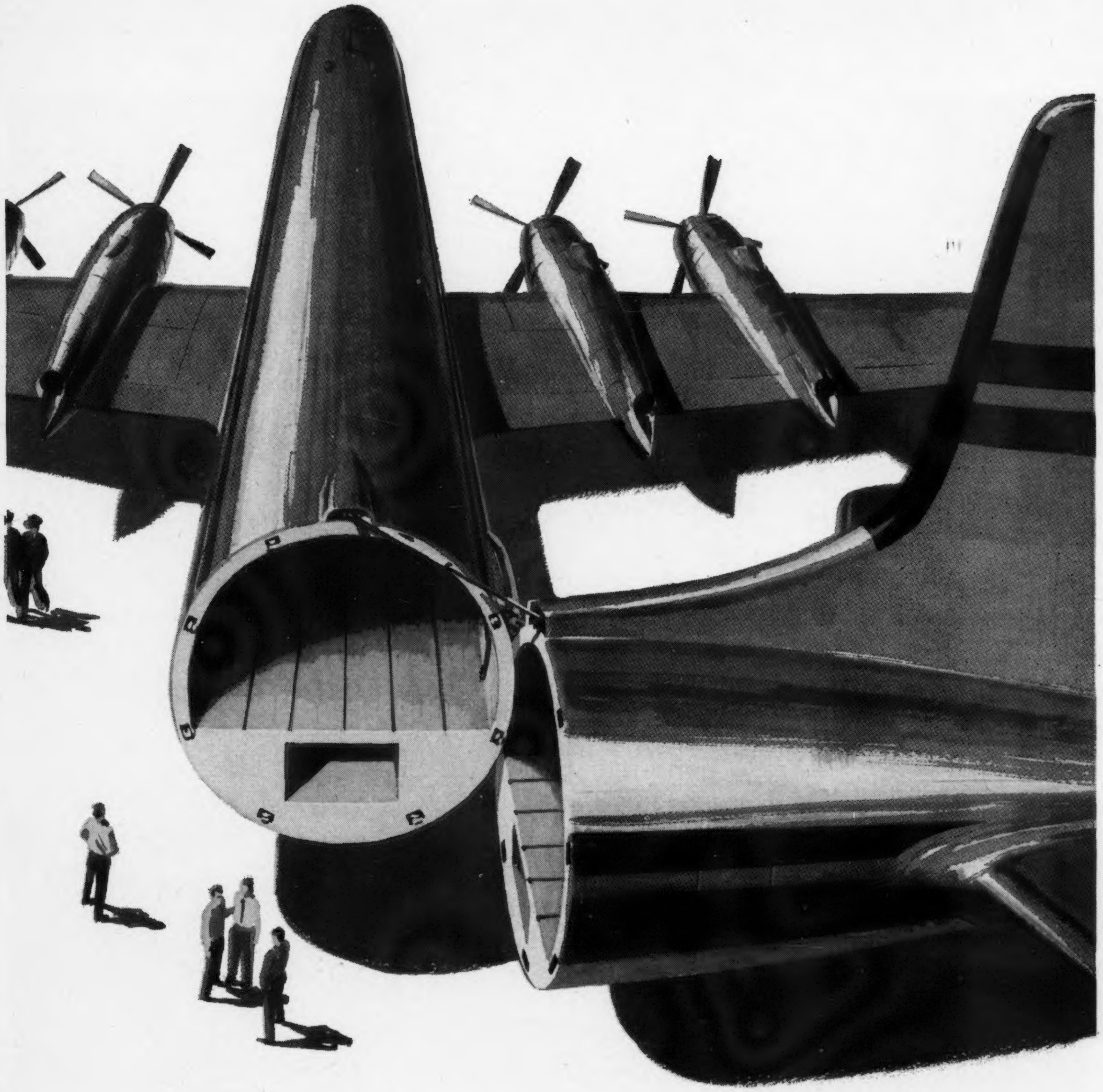

CANADIAN AERONAUTICAL INSTITUTE

CANADIAN AERONAUTICAL JOURNAL

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CL-41

The Canadair CL-41 shown undergoing initial flight trials. This aircraft is the first original design by Canadair Limited and is also the first aircraft to be powered by the Pratt and Whitney JT12 turbojet engine. (See page 42.)

EDITORIAL

CHANGING CONDITIONS

As an Edmontonian, I wish to extend a warm welcome to the members of the Canadian Aeronautical Institute who will attend the Mid-season Meeting of the Institute in Edmonton on February 19th and 20th. Edmonton was the home of many famous bush pilots in the 1930's and, while that era has passed, the city is still air-minded and, even with the changing times, air travel and the aircraft industry give employment to a considerable number of its citizens.

Yet, with all the advances there have been in aircraft since the days of the bush pilot, the industry faces problems and conditions today that will take courage, initiative and intelligence to solve. The end of World War II gave a great impetus to aviation in Canada. Not only did a large number of military aircraft that could be converted to civilian use become available but even more important, trained pilots, aircraft engineers, aircraft mechanics and aircraft administrators were available and eager to turn their wartime training to civilian aeronautical pursuits. The last fifteen years have seen the aeroplane become an accepted means of transporting travellers across continents and over oceans, and it has been suggested that the time is not far distant when trans-continental passenger trains will be a thing of the past.

Wartime aircraft are no longer adequate for first class scheduled airline operations, and even the bush operator and the flying businessman are turning to newly designed and constructed aircraft. These newer aircraft, because they are faster and bigger and, like all products constructed since the end of the war, reflect the effects of inflation, are many times more costly than the war surplus aircraft. Their increased cost presents a real problem to the aircraft operator, and most airlines find themselves in a never ending cycle of financing arrangements. The new aircraft's size and speed has permitted the airlines to hold or reduce their fares, and yet the same speed and size has reduced the number of aircraft required to transport a given number of passengers. There will never be anything like the number of DC-8's, 707's, Vanguards or Viscounts constructed as there were DC-3's. As a result, a few large companies will, in the future, supply most of the world's civilian aircraft. Unless there is a strong government policy, few large aircraft will be constructed in Canada and yet there is very definitely a place for the Canadian aircraft manufacturer, as two well known companies have demonstrated.

Missiles are changing the role of the Air Forces of the world. Canada is training fewer pilots than she did in the years immediately following the Korean War, and this reduced requirement is being reflected on the repair and overhaul industry. There is not the volume of civilian work to take the place of the diminishing military work load, and only through the combined efforts of government departments, manufacturers and operators will the civilian usage of aircraft be increased to partially offset the loss.

Other changes have taken place over the past few years. With the approval of the Air Transport Board, we now have two airlines flying in our national trans-continental routes. It is not difficult to find protagonists for and against airline competition. We, as Canadians, support a free enterprise system, and yet thoughtful free-enterprisers agree that airlines, being a public utility, should be treated like railroads, telephone systems or electrical distribution companies where duplication of facilities is regarded as an economic waste. Public utility facilities entail a much higher investment of fixed capital, in relation to sales or receipts, than is required for industry in general. The facility must be designed to insure the regular and adequate supply of the utility for which the franchise is granted. At the same time, the service must be produced and sold on terms that will permit adequate maintenance and replacement, and to attract additional investment funds for expanding demand. This reconciliation of the interests of the enterprise with the public interest is a basic objective of government supervision of public utilities, and is just as applicable to an air service as it is to any other form of public utility. The recent decision of the Government to remove Class 4B operators, in addition to Class 4C, from the public utility classification, and to place them in the position of having to face unlimited competition with very little traffic potential, is a problem which will have to be resolved by the Government and industry together.

It is not the object of this article to say what the answers to these problems should be, but I do suggest that the problems receive the consideration of the CAI. Such an organization, with its wide membership, can do much to find intelligent and workable solutions.

B. W. Pitfield
Vice-President and General Manager
Northwest Industries Limited

CANADAIR CL-41

CANADAIR Limited has announced that the CL-41 jet-powered, primary and basic trainer has completed a successful initial flight at Cartierville airport in Montreal.

The CL-41, a side-by-side two-seater, is the first entirely original design by Canadair and two prototypes have been built as a private venture. Foreign air attachés visiting the Montreal plant in recent months have shown extreme interest in the trainer, which is of a type suited for building under licence.

Side-by-side seating was adopted in the interests of greater instructor efficiency and in accordance with the indicated requirements of the Royal Canadian Air Force and the United States Air Force. This seating arrangement is also preferred for training airline pilots.

For the first time in any subsonic jet trainer, one of the new generation of high power-to-weight ratio turbojet engines is used – the Pratt & Whitney JT12. Although built in the United States the JT12 was designed and developed by the engineers at the Canadian Pratt & Whitney plant in Montreal. Demand for this promising engine made it expedient to transfer the programme to the parent company at East Hartford, Connecticut.

This engine has a takeoff thrust of 2,400 lb for a weight of only 430 lb. A power-to-weight ratio of 6.75:1 is available (2,900 lb thrust), but the associated higher thrust is not needed for the CL-41. The limitation on power also means a longer engine life because of the reduced turbine inlet temperature. The CL-41 is the first aeroplane to be powered by the JT12.

The aircraft has a highly efficient light alloy structure which has been designed to an ultimate load factor of 11. Combined with the very light engine used, this means that the aircraft is more rugged, economical and efficient a trainer than has been possible before. Takeoff gross weight is 6,500 lb. Span and length are 36 ft 4 in and 32 ft 0 in respectively.

The time to a height of 30,000 ft is 11.7 minutes and the service ceiling is 44,500 ft. The rate of climb is 1,400 ft/min at 30,000 ft, sufficient excess thrust thus being available for aerobatics and other manoeuvres at great heights.

A wide speed range – stall at 65 knots, level top speed of 412 knots – provides a good safety margin for operation at low altitude and at the same time permits realistic training in piloting and navigation at high speeds at altitude. The design diving Mach number of 0.8 and the use of large fuselage-mounted dive brakes give the CL-41 the highest rate of descent of any jet trainer. Over a 50 ft obstacle the takeoff distance is 1,830 ft and the landing distance is 1,920 ft, at maximum weight.

Canadair CL-41 jet trainer

Automatic pressurization and air conditioning are provided. Instructor and student can fly for extended periods at heights up to 18,000 ft without using oxygen and up to 38,000 ft (cabin altitude 23,000 ft) with oxygen.

An unusual aspect of the CL-41 is the use of a "T-tail", the horizontal tail surface being mounted atop the fin. For trainer aircraft this is a desirable feature because the vertical tail surfaces are not blanketed by the tailplane during violent aerobatic manoeuvres and the rudder is particularly effective for spin recovery.

Exhaustive spinning model tests show that the design satisfies both the British (RAE) and the United States (NASA) design spinning criteria. Particular attention has been given in the aerodynamic design to ensure that spin recovery will be quick and straightforward.

In many aircraft the distribution of fuel in the wings results in marginal spin and recovery characteristics because of the high rolling and yawing inertia and problems of fuel asymmetry to be overcome. The CL-41 carries all its fuel near the centre of gravity in crash-resistant fuselage cells, functioning as a single tank, which avoids these undesirable effects.

Safety features include the fitment of ejection seats; an unusually high limit speed of 175 knots for operation of undercarriage and flaps; the engine is protected by air intake debris guards which are in position when the undercarriage is down; a windshield of "bird-proof" glass; an "annunciator panel" with individual lights to warn of fire, electrical failure, overheating or similar dangers; simple, manually operated flying controls; inherently good ditching characteristics; and a structure with longitudinal beams to withstand crash-landing (a typical example of the ruggedness of the structure is the cockpit region which is stressed to take a crash case of 24 g).

PROTECTIVE FINISHES FOR AIRCRAFT AND COMPONENTS†

by P. E. Lamoureux*

Trans-Canada Air Lines

INTRODUCTION

The last few years have seen a tremendous amount of development in aircraft types and in their powerplants. This development has been accompanied by, and in many respects is the result of, vast improvements in material properties to achieve certain performance advantages. Thus, we have seen the introduction of exotic materials such as titanium and polyurethanes, improvements in the older aluminum alloys, high temperature-resistant nickel-base alloys, etc.

The new turbine powered airplanes which are currently being placed in service, such as the Douglas DC-8, Boeing 707, Vickers Vanguard, Lockheed Electra, De Havilland Comet, etc, embody very significant changes in basic structural concepts and in materials to achieve long and economical life of components. The finishes used throughout these airplanes are no exception; they are primarily designed to preserve the structural integrity of the materials used and to protect them against the corrosive environment to which all aircraft are constantly exposed in varying degree.

AIRFRAME STRUCTURES

The basic airframe structure of all commercial aircraft is essentially aluminum alloy. In large airplanes, many components in the wings are machined from large forgings embodying integral stiffening members, as shown in Figure 1. This means, of course, that such components are not protected by the usual cladding process which provides a thin layer of corrosion resistant unalloyed aluminum on the surface.

Traditionally, aluminum alloy components have been protected with organic coatings of the zinc chromate variety. These coatings are applied over aluminum after one of several chemical treatments. The purpose of the chemical treatment is to oxidize the surface to provide a thin protective oxide layer or to simply etch the surface to provide absolute cleanliness and thus achieve a good bond. Zinc chromate finishes are used extensively on all internal surfaces of the structure of these new airplanes and the binders or "vehicles" used in these finishes are especially designed to resist the effects of synthetic hydraulic fluids. Synthetic hydraulic fluids are used because of their relative incombustibility and the pressure lines are routed to virtually all parts of the airframe.

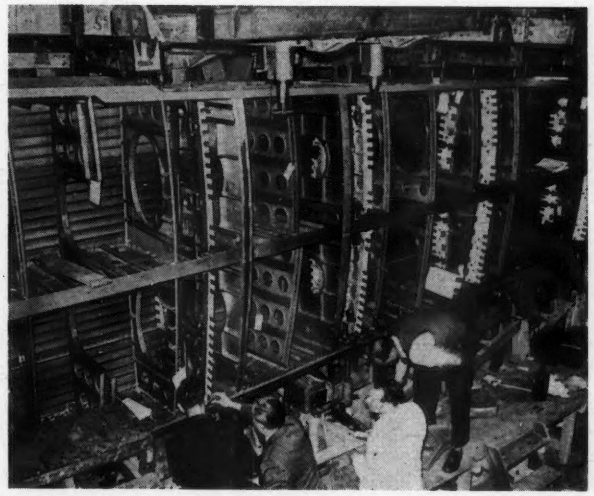

Figure 1
Wing assembly of the Vickers Vanguard showing integral wing skin and stiffening members

Because of the consequent problem of dripping and leaks at fittings, it is necessary to use finishes which are fully resistant to these fluids. The most popular of these synthetic hydraulic fluids is a phosphate ester material which has excellent paint removing capabilities on conventional finishes. Experience in the last few years has demonstrated that certain epoxy finishes are fully resistant to the effects of these fluids and yet retain the very desirable attribute of being removable with conventional paint removers.

For the same reason, certain areas of the exterior of the airframe which are susceptible to contamination by leakage of synthetic hydraulic fluids must be protected with epoxy finishes to achieve the necessary chemical resistance.

In the finishing of airframe structures, special attention must be paid to the contact areas where dissimilar metals are joined. For instance, the DC-8 airframe incorporates titanium "rip-stops" at each belt frame in the

†Received 23rd November, 1959.
*Materials and Process Engineer

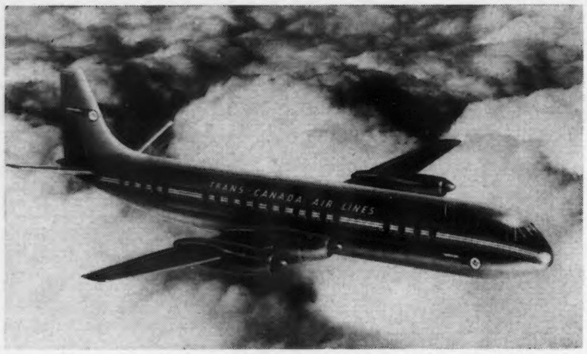

Figure 2
TCA Vanguard with all-over paint scheme

fuselage. Such areas must receive special attention to ensure that electrolyte from condensation will not set up a galvanic action which could result in serious and insidious corrosion in these important members.

The use of magnesium in commercial airframes has been largely discontinued because of a long history of unsatisfactory corrosion experience with this material. Satisfactory finishes are available for magnesium components but, unfortunately, during service, scratches are made through the finishes which expose the bare metal and modifications and attachments are made which require the use of screws and rivets. Invariably, such discontinuities in the surface finishes result in serious corrosion and expensive maintenance.

The exterior decorative appearance of the aircraft is gradually evolving. A few years ago, the exteriors of the aircraft were almost entirely devoid of finishes except for the identification letters and the company designations. In recent years, the trend has been to apply decorative schemes using organic coatings and more and more of the external surfaces of the aircraft are now treated with pigmented organic coatings. The use of a white top to reflect the sun's rays and to help keep cabins cool in the summer time is now almost universal. The white top has in certain cases been carried below the window line and even down to the floor line. The use of large painted patches on several parts of the aircraft to protect the underlying structures from the corrosive effects of galley and lavatory drains, cabin and heater exhaust, etc, is also quite common and beneficial. These, combined with the large wing areas which must be protected by paint because of the use of machined skins, and the application of functional coatings such as wing walkways and protective patches, accentuate the trend towards less uncoated aluminum and the greater use of painted finishes. As a matter of fact, some of the most recent aircraft, such as the Vickers Vanguard shown in Figure 2, will have all exterior surfaces painted.

Experience with these finishes has shown that they are long lived, easy to apply and maintain and can be renewed at a moment's notice. They act as a very effective barrier against corrosion and abrasion with the result that, where used judiciously, expensive skin replacement is virtually eliminated. Important also is the fact that painted aircraft do not require the expensive and time consuming polishing which uncoated aluminum, with its tendency to stain and oxidize, requires. Thus, grooming costs are reduced. For those airlines who wish to retain the lustre of polished aluminum, clear coatings are available which can be applied to the aluminum. The life of such coatings, however, and their ability to retain good transparency when subjected to abrasion and weathering still leaves much to be desired.

While on the subject of exterior finishes of airplanes, mention should be made of the catalyzed epoxy finishes, which combine high gloss with outstanding abrasion resistance, as well as virtually complete immunity to the several chemicals which are used in the maintenance of these aircraft or as fluids in the various systems. Tests with a particular brand of epoxy have shown that the material can actually replace some of the anti-abrasion rubberized coatings which are still commonly used on such components as radome housings. Figure 3 shows the appearance of a catalyzed epoxy finish on a radome housing.

Inside the cabin and cockpit of the aircraft, the trend is towards increased use of synthetic materials and especially the vinyls. These can be produced in a variety of surface textures, colours and gloss. One of the main problems with maintaining interior surfaces is the accumulation of stains resulting from the spillage of food, beverages, etc and especially the staining effect of tobacco smoke which gives an over-all brown cast to all exposed surfaces, especially sidewall and ceiling panels. Such stains are extremely obstinate and virtually impossible to remove. By the simple expedient of applying a coat of vinyl paint, these surfaces can be restored to their original new appearance at minimum cost. The same is true of leather covered surfaces which can be renewed by the simple application of a special organic coating.

ENGINE COMPONENTS

In the past, engine components have required a minimum number of finishes to protect them from corrosion and surface deterioration. This has been due to the fact that virtually all parts of the reciprocating engine are

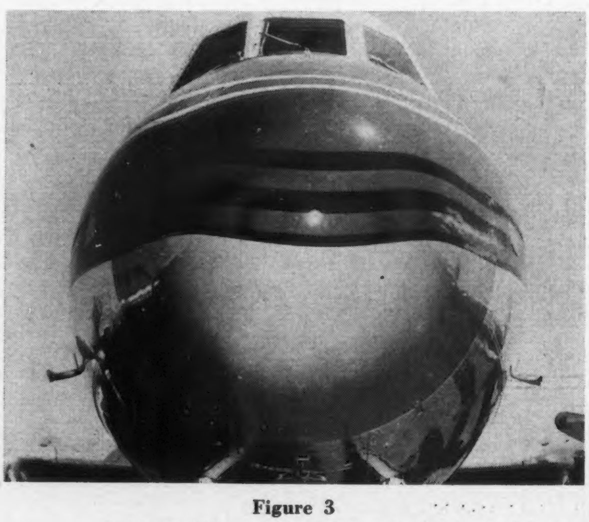

Figure 3
Radome with epoxy-base organic coating

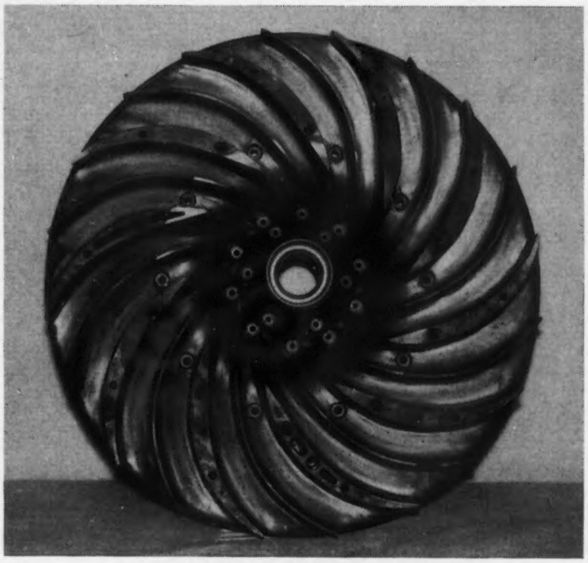

Figure 4
Diffuser guide vane with epoxy-base organic coating

constantly bathed in lubricating oil. The use of paint was limited to a small number of steel brackets and baffles, which were on the outside of the engine and, therefore, exposed to atmospheric effects. In the case of the turbine engine, lubrication is limited to the vital bearings of the rotating shafts, reduction gears and the accessory drives. This leaves a considerable amount of metal which is exposed to the air stream and therefore subject to moisture, dirt, etc. The engines also incorporate a number of large magnesium components, all the surfaces of which must be protected against corrosion. Current practice is to protect such vulnerable parts with organic finishes, generally of the phenolic variety.

Phenolics in engines give excellent performance and service but they pose a serious problem of removal for purposes of inspection of the underlying metal or renewal of the coating. Current tests with epoxy formulations of the type used on the exterior of the aircraft show considerable promise of success as finishes for engine components, both internal and external. Figure 4 illustrates a Dart diffuser guide vane with an epoxy-base coating.

The extensive use of steel in propeller blades and the occurrence of intergranular corrosion in aluminum propellers has created a trend towards painting of these with organic finishes. Here the conditions are extremely severe because of the wide range of deteriorating influences encountered, plus the constant sand blasting effect during ground operations. The use of organic finishes on propeller blades has not been entirely successful, but indications are that finishes will be found to last the full overhaul life of the propeller.

A brief mention should perhaps be made of the high visibility finishes which are now being used on the exterior of airplanes to enhance visibility and reduce the danger of collision. Such finishes are available in the form of paints or as vinyl base films which can be glued to the surfaces. The pigments used in these formulations are reasonably effective but, unfortunately, their life is limited to something less than a year. No doubt the intensive work which is going on in this field will bring about improvement in this respect. If used judiciously, these high visibility colours can serve the double purpose of improving the appearance of the aircraft as well as enhancing visibility.

CONCLUSION

The whole field of finishes for aircraft is constantly under review by the aircraft manufacturers and the operators, and tremendous strides have been made in the past few years. The advent of X-ray and other means of non-destructive testing, which do not call for the removal of finishes or even overlying structures such as cabin upholstery, is lending considerable incentive to the development and adoption of longer life and more resistant finishes. The larger size of the new aircraft and the need to reduce the amount of maintenance and time consumed in renewing finishes dictate a more aggressive search for the ultimate in the properties of aircraft finishes. The advent of such materials as the epoxies and polyurethanes has permitted great strides to be made in this direction and the future holds bright promises of better things to come.

TRAINING CENTER FOR EXPERIMENTAL AERODYNAMICS

The T.C.E.A., which was set up in 1956 at Rhode-Saint-Genese, Belgium, for the use of NATO nations, is inviting applications for its One-year Diploma Course in Experimental Aerodynamics for the year October 1960 to July 1961. The course is open to suitably-qualified graduate engineers and scientists, who must be a citizen of one of the nations of NATO and fluent in either English or French. There are no fees for the course and there are a number of fellowships to cover living expenses.

Application forms and further details can be obtained from C.A.I. Headquarters or from:

The Director,
Training Center for Experimental Aerodynamics,
72, Chaussee de Waterloo,
Rhode-Saint-Genese,
Belgium.

Applications must be filed by the 19th March, 1960.

SUPERSONIC TRANSPORTS — SOME DESIGN ASPECTS†

by L. T. Goodmanson*

Boeing Airplane Company

INTRODUCTION

Several years ago, when serious studies of supersonic transports were just getting underway, the prospect of transporting large numbers of passengers over long distances at speeds faster than sound seemed a most glamorous business. Then came Sputnik. Almost overnight talk of rockets, exit velocities and space travel reduced the supersonic transport to a relatively mundane position. In the new mood of "anything is probable" the potential characteristic of the supersonic transports grew rapidly — more rapidly, in my opinion, than is supported by current state-of-the-art. Advances in supersonic technology over the past decade have been significant but in the cold economic reality of airline operation they will hardly justify predictions of operational Mach 3.5 transports at an early date.

What will be the likely characteristics of the first supersonic transports? This paper discusses some of the factors which will influence choice of cruise speed, design range and airplane size. A number of the special problems associated with design and operation of supersonic transports are also discussed.

CONFIGURATION

First, let's look at a typical supersonic configuration (Figure 1). This airplane has many of the features which will characterize the supersonic transport: short wing span made necessary by the very thin airfoil required for low drag, long pointed body gradually fairing at front and back (also a concession to supersonic wave drag) and a long landing gear to provide the high attitude necessary to takeoff and land at reasonable speeds and distances. Other features of interest on this model include the canard which provides an efficient longitudinal trim and stabilizing surface if properly actuated, and further provides the possibility of direct mechanical control of the airplane without black boxes. The engines, in this case non-afterburning turbojets, are grouped at the aft end of the body. Engine air inlets, which change ramp angle with varying Mach number, are located at the wing leading edge.

The long inlet ducts alongside the body preclude installation of windows over a major portion of the cabin. As you know, there has been much discussion of the value of passenger windows to the traveller flying at very high altitudes; also, concern as to their safety from

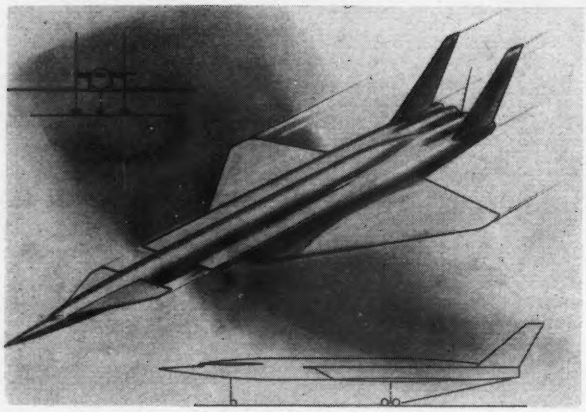

Figure 1
Supersonic transport — grouped engines

the decompression standpoint. One answer to both of these considerations is shown in Figure 2. The small flat-tube TV, here shown entertaining the passenger, would also provide him a better view of takeoff and landing operations than would a conventional side window. Snack service at the seats, here depicted by the coke and hot-dog dispenser, may replace today's seven course "stewardess served" dinner. A two-hour flight is hardly long enough to serve cocktails plus a full course dinner to over 100 people.

Figure 2
Television and hot dogs

†Based on a paper presented to the Vancouver Branch of the C.A.I. on the 20th October, 1959.
*Project Engineer

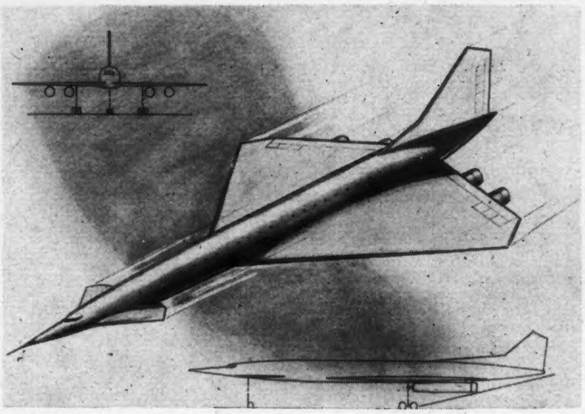

Figure 3
Supersonic transport — pods

Another configuration (Figure 3), also suitable for the Mach 2 to 3-plus speed range, mounts engines in pods beneath the wings. In this case, inlet control is accomplished by a central spike which translates fore and aft. Passengers who prefer to look through windows rather than at a TV tube may prefer this configuration.

SPEED SELECTION

A number of factors influence the choice of a proper cruise speed for the supersonic transport. Perhaps the most basic factor is travel time. Plotted on Figure 4 is block time vs cruise Mach number for intercontinental range. Note that block time rapidly improves through the low Mach number region, but that it levels out to a nearly constant value at high Mach numbers. The "knee" of the curve appears to lie in the $M = 2$ to 3 region. It would appear that cruise speeds greater than $M = 3$ will not pay off with appreciable time saving to the traveller.

The cost of increasing speed can be large, due principally to the rapid increase in temperature. Some of the factors which influence the effort which must be expended as speed increases are shown in Figure 5. To go appreciably faster than Mach 2, the more expensive "hard" structural materials will be required. Depending

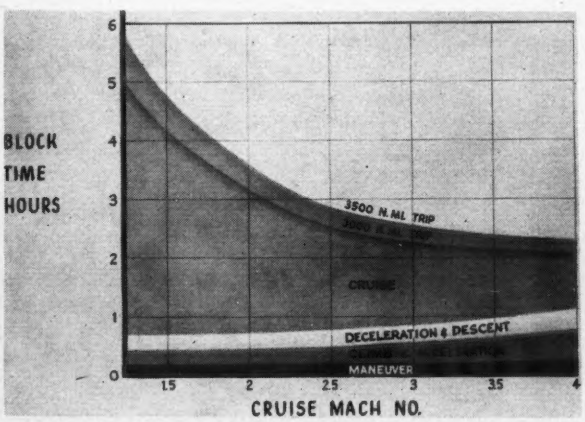

Figure 4
Cruise speed — effect on block time

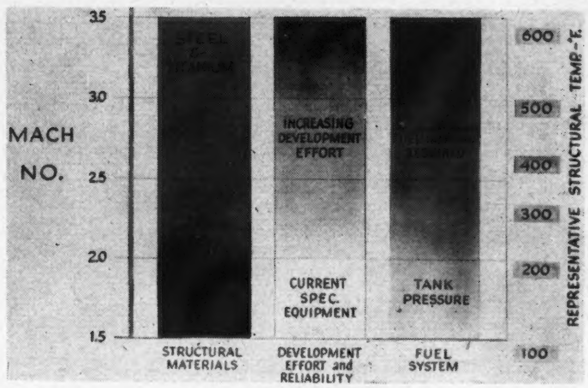

Figure 5
Speed selection

upon the speed, an increasing development effort on systems and equipment will be required to provide the high level of reliability necessary for commercial airline operation. Increased fuel tank pressurization will be necessary to prevent fuel boil-off at the higher temperatures and, for flight above about Mach 2.8, a positively reliable fuel tank inerting system must be installed to assure flight safety. At this speed, the temperature is high enough for fuel vapour to ignite spontaneously.

Now, let us consider some of the aerodynamic inputs on speed selection. Figure 6 will be familiar to those who have glanced at any articles on supersonic transports because almost all papers on the subject include a curve of this type. The aerodynamic and propulsion terms of the Bréguet cruise range equation are here plotted against Mach number. The very large reduction in lift/drag ratio for supersonic designs as compared with subsonic designs is compensated by the rapidly improving efficiency of the jet engine (V/SFC) at increased speed. Range factor, the product of these two terms, shows a sharp drop in the transonic region but increases substantially at higher speeds. This range factor curve is often used to indicate the desirability for the highest possible supersonic cruise speed. Proponents of high speed point out that if speed is high enough – say $M = 3.5$ – the super-

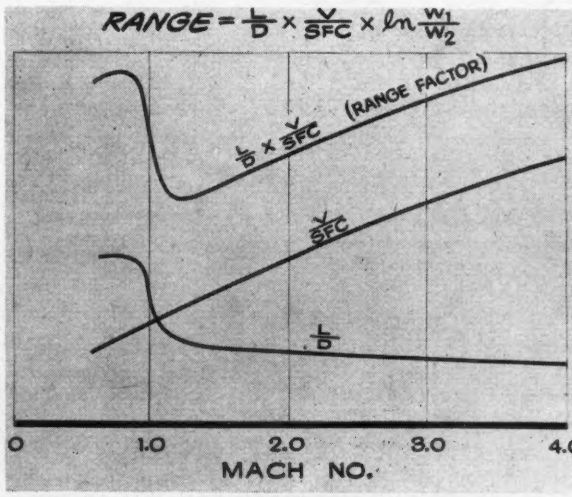

Figure 6
Cruise efficiency

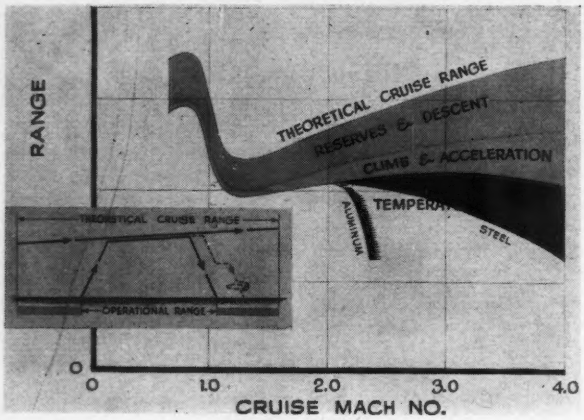

Figure 7
Operational range

sonic transport can provide the same cruise range as the subsonic jets, which enjoy the range factor peak in the region of $M = 0.8$. However, cruise range is only a part of the picture.

Figure 7 adds the other factors which must be included for a true range comparison of subsonic and supersonic transports. The top curve, "theoretical cruise range", is directly proportional to range factor shown on the preceding figure. It shows the variation of cruise range vs speed for a family of airplanes all having identical takeoff weights, equal payload and fuel load. This curve assumes that all the fuel is burned at cruise speed and altitude (as indicated on the flight profile insert). Now let us compare theoretical cruise range with operational range.

Some of the fuel loaded aboard the airplane is reserve allowance and no distance can be credited as it is not burned on a normal mission. Deducting this distance, and adjusting descent fuel distance, drops us to the second line; this line has a flatter slope than the top one because of the increasing amount of reserve fuel required by the faster airplane. Current CAR fuel reserve requirements were assumed.

The distance covered in climb and acceleration to cruise speed and altitude is less than that covered by burning the same amount of fuel in cruise. Much more energy must be expended to reach Mach 3 and a 60,000 ft altitude than to reach Mach 0.8 at 30,000 ft, consequently, the slope of the curve is again flattened.

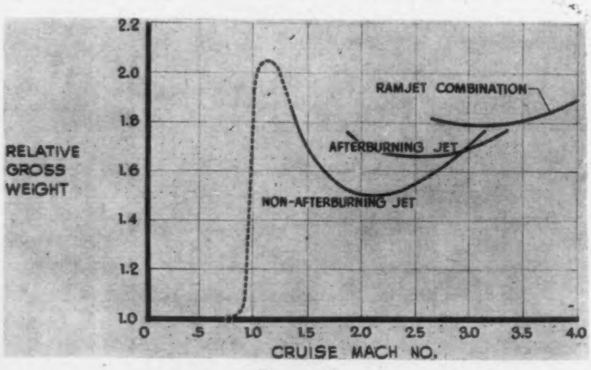

Figure 8
Airplane size — constant payload-range

So far we have assumed identical weights for all airplanes. Our studies indicate this is a reasonable assumption up to temperatures at which structural materials begin to lose strength. Above about 200°F ($M = 2$) strength of metals starts to drop off: aluminum very rapidly, steel and titanium relatively slowly. Weight empty goes up, consequently, fuel carried goes down, so range is reduced at speeds appreciably above Mach 2. From the lower curve it is concluded that the region close to Mach 2 is of principal interest for aluminum airplanes. A steel airplane would have reasonably good range capabilities at a speed of Mach 2.5. Operational range falls off quite rapidly at speeds above Mach 3.

Relative size of airplanes required to carry a given payload over a given range is given as a function of cruise Mach number in Figure 8. Airplane size is related to that of a subsonic jet cruising at Mach 0.8. It would appear that the minimum size supersonic airplane will cruise at a speed in the region of Mach 2. Several of the possible engine types which might be used on the supersonic transport are indicated. Non-afterburning jets are a likely choice for cruise at Mach 2 to near 3. Afterburning jets are of interest in the region of Mach 3. Ramjets, in combination with turbojets for takeoff and climb, come into their own at speeds above Mach 3.5.

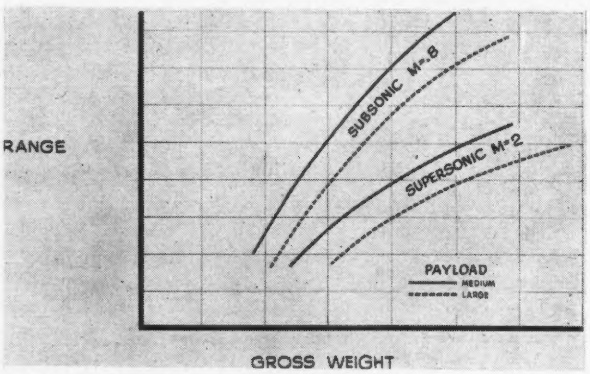

Figure 9
Airplane size comparison

DESIGN RANGE

Range-payload capability of Mach 2 supersonic transports is compared with that of subsonic transports in Figure 9. Every point on each curve represents an airplane specifically designed to do the payload-range job indicated. Note that supersonic airplane size increases much more rapidly with increasing range than does subsonic airplane size. Unless some significant technical break-through is discovered — aerodynamic, propulsive or structural — it appears that the very long range supersonic transport, carrying a reasonable payload, will be a very large airplane.

Let us consider the range requirement for the supersonic transport in view of the very steep trade between airplane range and size. Historically, with every increase in transport cruise speed, there has been an increase in range. The ultimate long range subsonic jet will undoubtedly have an operational range in excess of 5,000 nautical miles. This range is possible, based on today's technology, at a takeoff weight in the order of 350,000 lb. However, unless there are further, and fairly large, im-

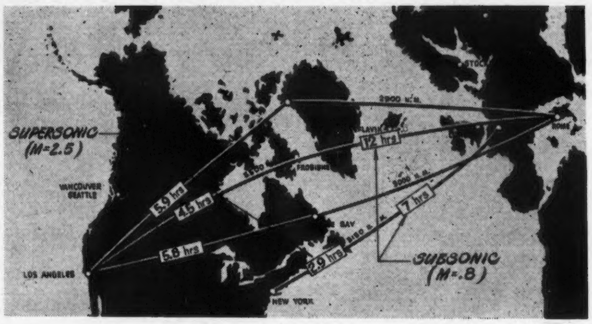

Figure 10
Trip time — North America — Europe

provements in supersonic technology, it may not be practical for the supersonic transport to continue the trend toward longer range as well as higher speed. Certainly the airline operator would prefer something smaller than a million pound monster on his ramp – no matter how far distant the desired destination.

The important factor to the air traveller is time. Due to the great jump in speed provided by the supersonic airplane, it can provide a major time saving on long trips even if an en route stop is necessary. Figure 10 pictures a typical very long range polar flight – Los Angeles to Rome. The non-stop subsonic jet would require about 12 hours for this 5,500 nautical mile jaunt. A Mach 2.5 supersonic transport would take less than 6 hours – allowing for a half-hour fuel stop at one of the several landing fields which might be used. Takeoff weight of the one-stop supersonic airplane would be about the same as for the non-stop subsonic jet, adequate to give it a non-stop capability on the North Atlantic.

Comparative travel times for subsonic and supersonic airplanes are plotted vs range in Figure 11. Even though a stop is required at longer ranges to keep supersonic airplane size within reason, it appears that the supersonic transport will cut travel time approximately in half. It is recognized that there are many reasons to avoid a stop: maintaining extra airports, weather, schedule reliability, to mention a few – all of which mean added operating headaches and expense. However, as there is probably some reasonably upper limit on acceptable airplane size, it may be necessary to live with some of these inconveniences.

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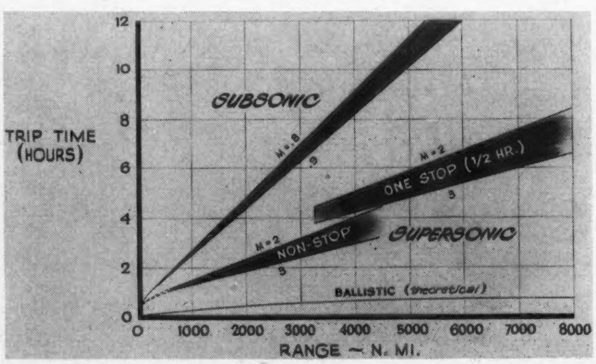

Figure 11
Trip time

curve which speculates on travel in a time period following the supersonic transports. The time shown for the ballistic assumes infinite accelerations at each end of the journey. Very high accelerations are one of several problems to be solved before ballistic travel comes into its own. I purposely did not use the term "ultimate" in describing the ballistic curve. Boeing's Preliminary Design Chief has made a statement which does perhaps describe the final ultra in global travel. "After man has taught himself to fly at many times the speed of sound, maybe he will expose himself to electronic disintegration, be transmitted over a co-axial cable and be instantaneously re-assembled at the other end. But even when he comes to this he still will demand safety, reliability and economy in his transportation and probably want a highball on the way."

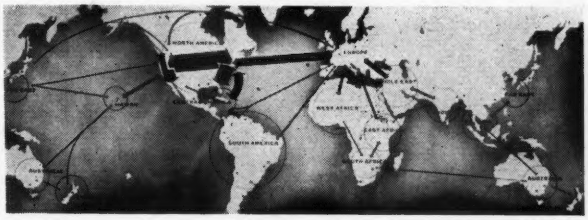

Figure 12
World air traffic flow

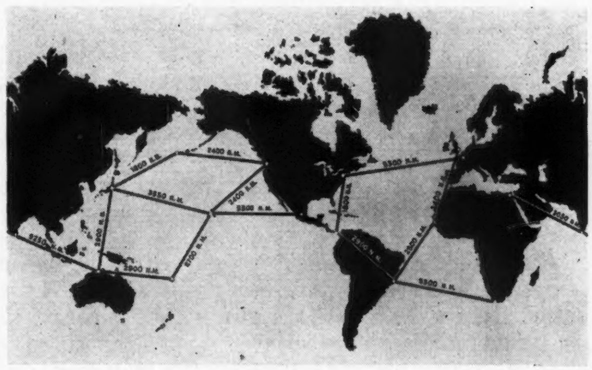

Figure 13
Air distances

AIR TRAFFIC

What minimum non-stop capability should the supersonic airplane have? We would certainly wish to provide non-stop operation on the most highly travelled routes. Relative traffic density on today's air routes is indicated approximately by the width of the arrows in Figure 12. This map would indicate that the supersonic transport must certainly fly the North Atlantic both ways non-stop. I purposely ignore the widest arrow – transcontinental North American traffic – because of the sonic boom problems discussed later.

The supersonic transport must have a global capability. Although it is unlikely that it will have the range necessary to go non-stop over all the major air routes, existing and potential, it must at least fit into the geography of a world which has remained relatively unchanged for a long time. The magic appearance of new islands, suitable for 10,000 ft landing fields, is most unlikely. Figure 13, which shows air distances in the pattern

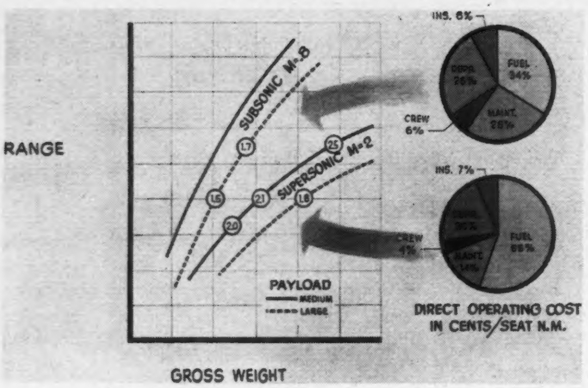

Figure 14
Comparative operating cost

of current and projected air traffic would indicate that an operational range approaching 3,500 nautical miles is reasonable for the supersonic transport.

OPERATING COSTS

Figure 14 adds operating cost data to the range-gross weight grid previously presented. DOC's are tabulated in the circles. It is apparent that supersonic operating costs are considerably higher than subsonic costs at equal range. However, the one-stop supersonic airplane, discussed earlier, has DOC's comparable to the subsonic long range airplane. The ATA method of computing DOC was used assuming 8 hour a day utilization, 750 hours between engine overhaul and fuel at 19c per gallon.

Approximate breakdown of subsonic and supersonic operating costs is shown by the "pie charts" on the right side of Figure 14. The most important difference is the major increase in fuel cost of the supersonic airplane. Much of this fuel cost percentage increase is due to the large amount of fuel burned reaching the higher cruise speed and altitude at which it operates.

Operating costs given in Figure 14 are for design ranges. At lower ranges, due principally to the drop in block speed, DOC's go up. Figure 15 shows the effect of reduced range on supersonic airplanes designed in one case for 3,500 nautical miles and in the other for 5,500 nautical miles. A 707 curve is shown for comparison. It is apparent that a supersonic airplane designed for extreme ranges will be less competitive at short ranges than will the supersonic transport with a more moderate design range.

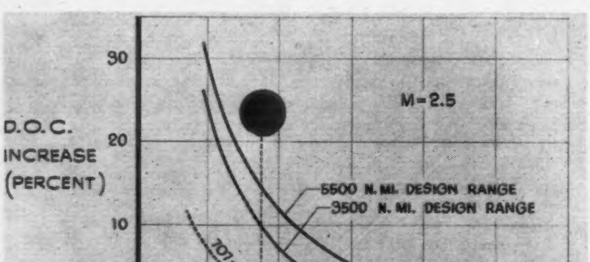

Figure 15
Operating cost at reduced range

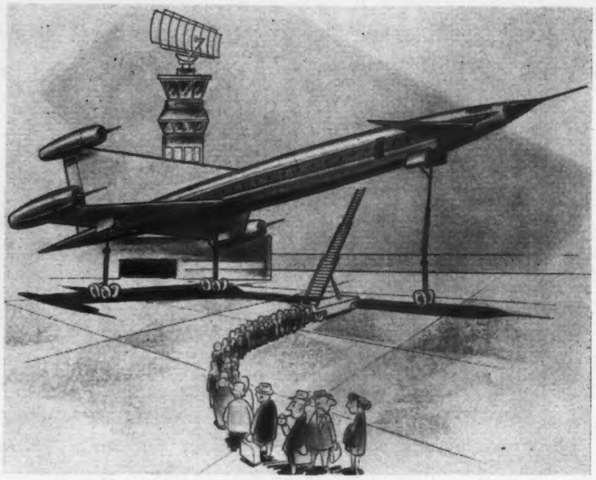

Figure 16
The "supersonic seventies"

PROBLEM AREAS

We have considered speed, range and size. Now how about some of the problems pertinent to the supersonic transport? Figure 16, a cartoon which appeared in the September, 1959, issue of *Interavia* over an article by Peter Masefield entitled "The Supersonic Seventies", provides a good introduction to this subject. Some potential operational problems, highly caricaturized here, are nonetheless quite apparent.

One of the potential problems of the supersonic transport to the airline operator is its extreme productivity. Work capability of supersonic airplanes is compared with that of current aircraft in Figure 17. One supersonic airliner can do the work of two or three 707's. It will transport more people than will the Queen Mary in a given time. From the operator's standpoint, it would be desirable to have more but smaller supersonic airplanes, carrying perhaps only 50 to 60 passengers. However, from the range and operating cost standpoints discussed earlier, it is evident that sizing the airplane to carry such small payloads over long distances would not be economically sound. Smaller fleet sizes and perhaps fewer trunk airlines may result because of the high productivity of supersonic transports. However, the anticipated continued rapid growth in air travel (stimulated by

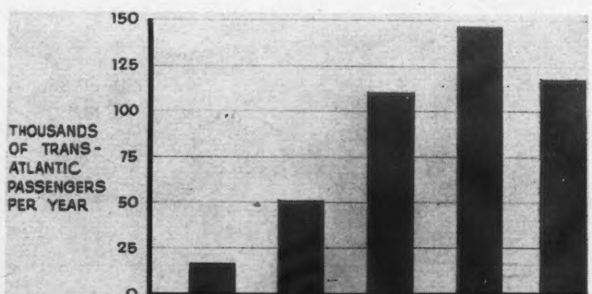

Figure 17
Work capability per airplane

the jets and undoubtedly to be further stimulated by supersonic types when introduced) will be a major compensating factor.

Will the supersonic operator get reasonable utilization out of small fleets of supersonic transports? Figure 18 shows how a four airplane fleet might operate across the North Atlantic. Arrivals and departures are confined generally to the 7.00 am to midnight hours. One exception is the flight indicated by the bar at the far right showing a 1.30 am departure from Paris. The novelty of arriving in New York at 10.00 pm of the previous night might take much of the sting out of this early morning departure. The fairly long turn-arounds shown provide good departure protection on most flights. The New York-Miami schedule, though too short to use the airplane to its best advantage, does utilize it at a time it would otherwise be sitting on the ground awaiting a reasonable arrival hour in Paris. A combination of East-West and North-South routes will certainly improve utilization of airplanes whose speed completely outstrips the clock. The New York-Paris schedule provides a fleet utilization of 7½ hours per day. Adding the Miami flights increases daily utilization to 9 hours. Adequate "home base" time is still available for progressive maintenance and overhaul.

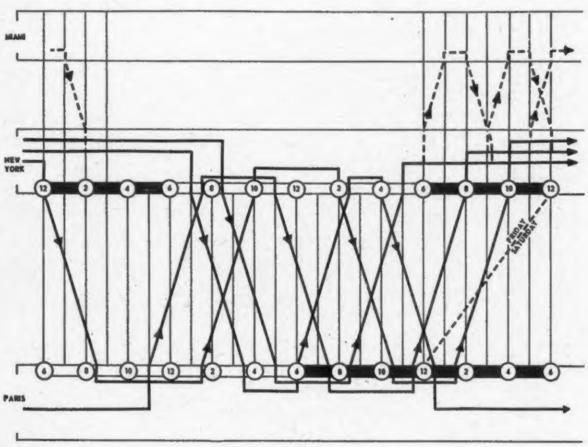

Figure 18
Flight schedules
Paris — New York — Miami

The structure of the supersonic transport will differ appreciably from current types. Figure 19 plots unit end load on the upper wing surface along its span – comparing the supersonic, low-aspect ratio type with the subsonic, high-aspect ratio wing. The markedly reduced load on the supersonic wing requires less bending material as shown. The thinner wing skin must have closely spaced supports to prevent buckling. Thus, the skin-stringer configuration in current use does not appear to be competitive with sandwich types. Bonded aluminum honeycomb sandwich or brazed steel honeycomb are the two types of structures most commonly planned for Mach 2 and Mach 3 speeds respectively. Unfortunately brazed steel honeycomb is, today, very costly compared with either aluminum skin-stringer or honeycomb construction. A low cost steel structure suitable for super-

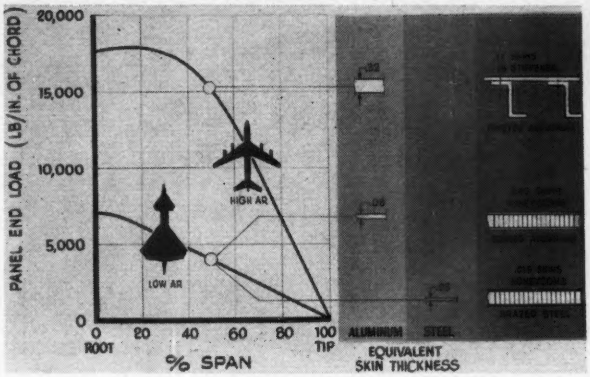

Figure 19
Wing structure

sonic configuration must be developed before the greater speed of the steel airplane can be applied to economic transport operation.

Another problem which has been widely discussed in connection with supersonic airplanes is explosive decompression. What would happen if a window or hatch should blow out at 70,000 ft? First, it should be pointed out that the design must provide the structural integrity to make such a circumstance virtually impossible. A safety device such as that depicted in Figure 20 would provide additional protection for passengers and crew should a blow-out occur. Sudden loss in cabin pressure would trigger an airscoop to extend into the main airstream. Thus ram air, cooled by a water spray, would partially pressurize the cabin during the descent. With the aid of simple oxygen masks as furnished on today's jets, passengers would be protected until the airplane was down to a safe altitude. Incidentally, drag of the air scoop would help to provide the high drag desirable for rapid airplane rate of descent.

Cabin cooling is an area of considerable interest for the supersonic transport. Numerous ways to keep the cabin cool have been suggested – including, for example, water-jacketing of the cabin walls. Two somewhat more

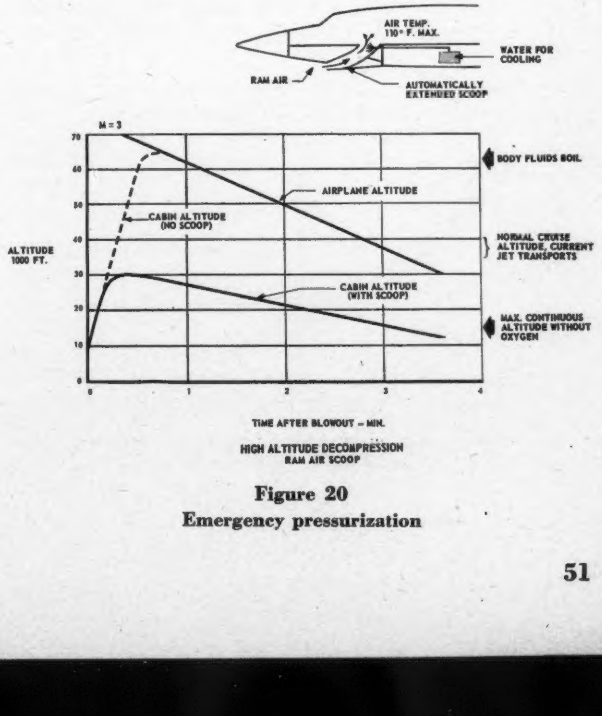

Figure 20
Emergency pressurization

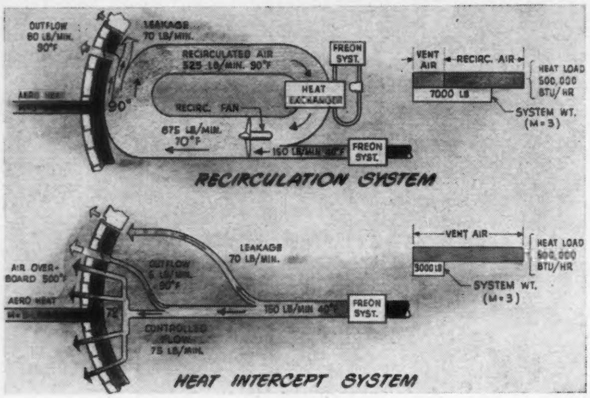

Figure 21
Cabin cooling

conventional systems are compared in Figure 21. The upper method cools inflow air by a refrigeration system and recirculates a large proportion of the inflow air. An additional refrigeration-heat exchanger system is employed to cool the recirculating air. Maximum cabin wall temperatures, here shown as 90°F, will determine size and weight of the recirculating air cooling system.

A new system which has been developed recently in connection with Boeing's supersonic work is that shown schematically on the lower portion of the figure. In this case, the cabin walls are themselves used as a heat exchanger by providing air exit flow paths through the insulation. Heat entering through the walls is "intercepted", if you will, by the outgoing flow, thus the inner wall can be kept much cooler. Tests indicate 72°F is a reasonable maximum wall temperature. The heat intercept system would be much simpler and weigh less than half the weight of a recirculating system at Mach 3 speeds.

SONIC BOOM

A final problem I'd like to discuss is the sonic boom. This is the phenomenon created by compression of the air when an airplane flies through it faster than pressure waves can travel in the air. The many pressure disturbances, caused by the various portions of the airplane,

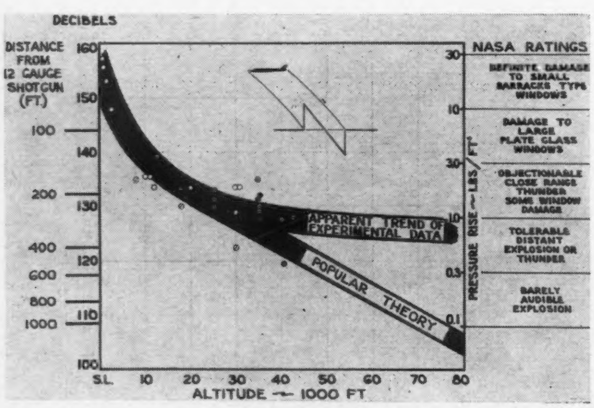

Figure 22
Sonic boom

combine into a single wave which goes out radially in all directions – including down. When it hits the ground the population hears a "boom" – and gets upset.

Intensity of the boom varies with altitude as indicated by Figure 22. The scale on the left will give hunters among the readers a feel for how loud. The ratings on the right indicate subjective reactions to sonic boom established by NASA. As recently as six months ago, it was believed that intensity of the boom varied with altitude according to the lower line, marked "Popular Theory". This line would indicate that once an airplane reached cruise altitude – say 60,000 ft – the boom heard on the ground would be so slight that it would not create a nuisance problem. Therefore, the supersonic transport operator could avoid sonic boom complaints if he routed his airplane away from populated areas only during climbs and descents at speeds above sonic.

However, additional data were obtained last spring and summer which began to show a much less favourable reduction in boom intensity with altitude. We at Boeing undertook a study program to find out why. Figure 23 presents the results of this work. The popular theory on sonic boom accounts for the disturbance created by the volume of the airplane and neglects the effect of airplane

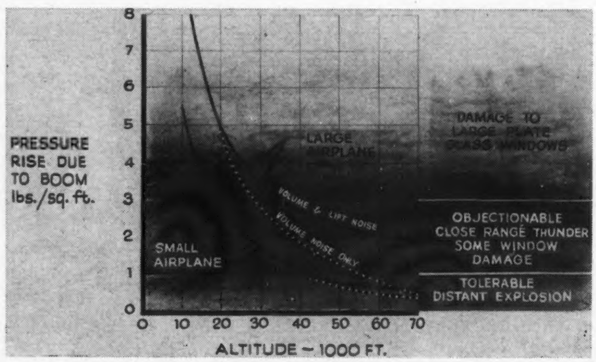

Figure 23
Sonic boom — wing lift

lift. For small fighter type airplanes flying at 40,000 ft or below, this simplification is permissible. However, for large bombers or transport aircraft flying at higher altitudes, the effect of lift cannot be neglected. Sonic boom, as you can see, is more serious than had been predicted. Unless people will become accustomed to close range thunder – on clear days – unless they will accept this new noise as yet another cost of progress, the only alternative will be to fly our supersonic transports only over oceans and over land areas of very low population.

MARKET POTENTIAL

Route restrictions because of sonic boom will, of course, affect the potential market for supersonic transports. Figure 24 shows a projection of free-world air travel over the next 15 years. It assumes a 15% per year increase to 1965 and 10% per year thereafter. In establishing the supersonic market, we have discarded all travel at ranges less than 2,000 miles from the standpoint of economics, discussed earlier. Of the long range travel,

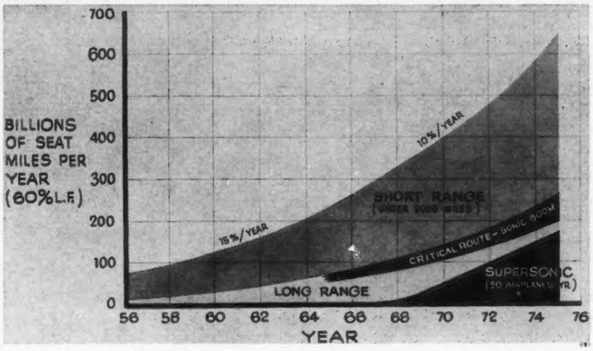

Figure 24
Market potential

our studies indicate that about 25% will be over populated areas which are critical for sonic boom. For example, it was assumed that all North American transcontinental traffic (currently about 10% of the total free-world "over 2,000" mile traffic) will remain subsonic. The lower area of the plot (75% of the total long range travel) is the portion of the market for which the supersonic transport will compete. This is a sizeable market — sufficient to support a free-world production rate in the order of 50 supersonic transports per year.

How effectively can the supersonic transport compete for this market? Based on current knowledge, it is evident that cost of a supersonic ticket will be somewhat higher than subsonic fare. Many people will be willing to pay the higher price to cut their travel time in half. However, supersonic operating costs must be reduced if the supersonic transport is to take over the entire long range market. It is anticipated that continued supersonic research and development will gradually reduce the DOC difference between supersonic and subsonic types. Eventually the supersonic transport may be expected to be truly competitive with his subsonic brother. When this stage of development is attained, the ballistic experts will probably have figured out how to carry passengers safely and comfortably at a cost not too much higher than the supersonic transport. But the ballistics people won't be allowed any relaxation either, for by then the electronics wizards may have mastered electronic disintegration and reassembly and be working feverously on the other problem posed earlier — how to pour a highball in a co-ax cable.

McCURDY AWARD

The McCurdy Award will be presented at the Annual General Meeting which will be held on the 24th and 25th May, 1960.

It is presented each year

To A Resident of Canada,

For Achievement in design, manufacture or maintenance related to aeronautics.

NOMINATIONS ARE INVITED

Each nomination should include

(a) The name and affiliation of the nominee,

(b) Confirmation that he is a resident of Canada,

(c) A citation of the particular achievement for which the nomination is being put forward, and

(d) The name of the nominator.

The nominee need not be a member of the C.A.I. and the achievement need not have taken place within the last year, though it should be recent.

Nominations should be in the hands of the Secretary not later than the 15th March, on which date they will be handed over to the McCurdy Award Selection Committee.

SOME THOUGHTS ON THE NEXT FIFTY YEARS OF FLIGHT†

by W/C P. A. Hartman*

Royal Canadian Air Force

INTRODUCTION

ALTHOUGH I shall present some thoughts on the next fifty years of flight, this paper might be more correctly entitled "The Third Phase of Flight" or "The Shape of Things to Come". Specifically, I shall talk about the development of large civil transport aircraft having a vertical takeoff and landing capability. For one to assume the role of a prophet is somewhat risky, particularly when it is a pilot attempting to point the way for aircraft designers. However, I have rationalized my action with the certain knowledge that if future developments prove me to have been wrong, I shall merely be relegated to the company of those supposedly learned men who were proving manned flight in heavier-than-air craft to be impossible while the Wright Brothers were making their first powered flights.

The presenting of one's thoughts on the next fifty years of flight is not an easy task in times like these, when considerations of security must limit discussion of certain advanced technical matters. That I, like others, have had to work within these limitations you will readily accept, and I make no further apology for suitably restricting my comments. The opinions expressed are my own and do not necessarily reflect the views of the RCAF.

In the western world the military side of aviation is an essential factor in ensuring peace. It provides the stable atmosphere within which the civil side of aviation can be exploited for the common good[1]. On the assumption that this stability will not be disturbed, the following analysis and forecast is limited to the civil aspects of aviation; there will, of course, be certain obvious military applications and benefits.

PROGRESS ACHIEVED TO DATE

A study of the history of flight shows that progress to date has been an evolutionary process consisting of two phases; firstly, the vertical takeoff phase using the lighter-than-air craft, which began with the balloon and culminated with the airship, and, secondly, the inclined-plane takeoff phase initiated by the heavier-than-air craft, the aeroplane. Within these two phases technical advances have been progressively applied in accordance with certain physical laws and requirements. A detailed analysis of the past will not only verify the existence of these two phases, but also establish the imminence of the third phase. This third phase will again be the vertical takeoff phase, but with the heavier-than-air craft, the aeroplane, and with a radical change in the configuration of the craft. (No, I have not forgotten the helicopter; although it is a distinct and separate entity within the second phase, it is regarded as being merely a clever, albeit inherently inefficient, adaptation of the principles of design inherent in the second phase.)

First phase

The first, or vertical takeoff, phase began in 1783, with the invention of the balloon which subsequently attained a limited degree of utility and flexibility when it emerged as the airship powered by the internal combustion engine. Although both steam and electricity were used, with varying degrees of success, to power the airship, the first significant advances in the airship came with the introduction of the gasoline engine in 1897, and the use of a metal clad structure which provided rigidity[2].

The advent of the lightweight internal combustion engine heralded the end of the airship as a commercial carrier, although it continues in certain military roles. However, it persisted in the commercial field until the catastrophic event at Lakehurst, N.J., on May 6th, 1937. It was apparent for some time before this final event that the requirement for increased speed, upon the attainment of which commercial productivity was dependent, would ultimately defeat the airship. The inherent high airframe drag of the craft rendered it incapable of fulfilling this emerging requirement.

Second phase

The second phase began when the Wright Brothers, with their analytical approach and common sense, were able to combine the glider and the internal combustion engine. The subsequent developments and advances in the field of aeronautics are familiar to all of you.

†Paper read at the Annual General Meeting of the C.A.I. in Keltic Lodge, Ingonish, N.S., on the 17th June, 1959.

*Directorate of Maritime, Transport and Tactical Training Requirements

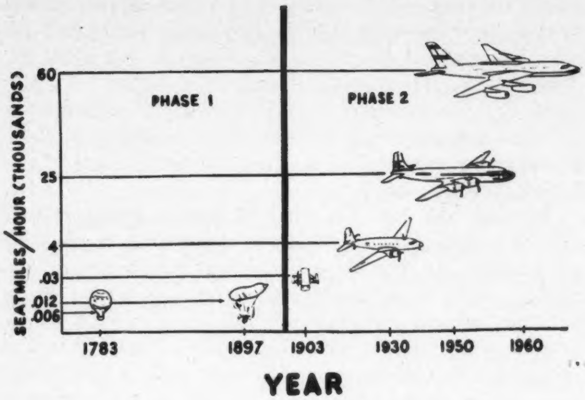

Figure 1
Production capacity vs time

Therefore, I shall not review in detail the progress that has been achieved. It will suffice to note that the period from 1903 to 1945 was one of innumerable refinements in design. The strut and wire biplane was displaced by the cantilever winged monoplane. Drag producing protuberances disappeared and the undercarriage folded out of sight. It was a period during which the aircraft's performance was limited primarily by the power available from the reciprocating internal combustion engine. This limitation was subsequently reduced following the introduction of the turbojet engine. Figure 1 illustrates the two phases and the progress achieved in each expressed as productivity in seat-miles/hour.

It was during the initial stages of this phase, however, that the aircraft was most flexible in its ability to take off and land from unprepared areas. Many of you will recall the farmer's fields from which you watched with awe the first aeroplanes operate. However, advances in performance and productivity began to reduce the aircraft's flexibility because of the need for longer runways. Consequently, this need began to limit the areas which the aircraft could serve.

Present

The requirement for increased speed prevails and is manifest by the emerging generation of medium and long range turbine-powered transport aircraft. These aircraft are larger, faster and more costly than their predecessors. Their annual productivity exceeds by a factor of three that of the latest piston-engined types. Their efficient, economical utilization is, however, vitally dependent upon the regularity and frequency with which they can be operated[3]. These latter factors will, in turn, determine the operating revenues to be derived and the additional traffic they can generate.

However, their higher en route speed, which determines to a vital extent their greater productivity, may well be squandered by reason of a design configuration which necessitates the retention of an inclined-plane profile for takeoff and landing. Those of you today, who frequently travel via the commercial airlines have, I am certain, experienced periodically the time-consuming and frustrating delays entailed by the aircraft in which you are riding having to "hold" over beacons during inclement weather, while awaiting its turn to approach and land. The airline time-table becomes meaningless when weather minima drop to 500 ft and ½ mile. This situation arises primarily because all in-bound traffic, no matter from what point of the compass it approaches the landing area, must normally be painstakingly funnelled down and into a single slot for landing. Additional delays are incurred by the necessity to allow outward bound aircraft to depart. Thus, the maintenance of scheduled arrivals and departures at busy aerodromes varies directly with weather conditions and the number of aircraft using the aerodrome within a given time period.

The disruption of scheduled service has a markedly adverse effect on the economy and efficiency of commercial operations, because the attainment of the required utilization rate is not possible. In addition, the margin between profit and loss has been narrowed appreciably for the airline operator with the introduction of the turbojet transport. These modern transport aircraft require even longer runways. Thus, the areas which they can service are being further reduced by the lack of suitable aerodromes. This reduction in the number of usable aerodromes makes the selection of an alternate difficult and imposes an additional penalty in terms of reserve fuel requirements. It is interesting, but somewhat alarming, to note that proposals for future supersonic aircraft promise to limit further the number of aerodromes that can be used.

PROPOSALS FOR THE FUTURE

Although the ink has scarcely had time to dry on the present contracts for subsonic jet transport aircraft, the representatives of various aircraft manufacturers have begun planning for the introduction of Mach 2.0 – 3.0 transport aircraft[4]. It is clear, therefore, that speed is of paramount importance in future commercial carriers.

Figure 2 shows the increase in maximum speed attained by transport aircraft during the period 1914 to 1959. The speed versus time curve for the bomber air-

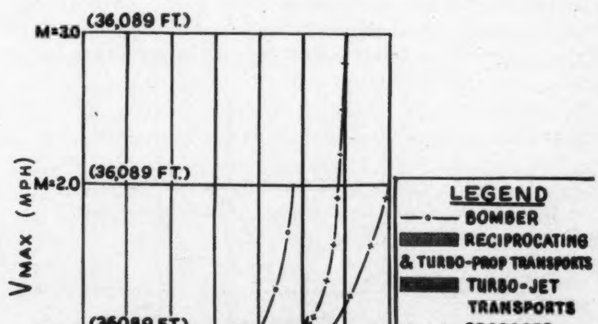

Figure 2
Maximum speed — transport aircraft

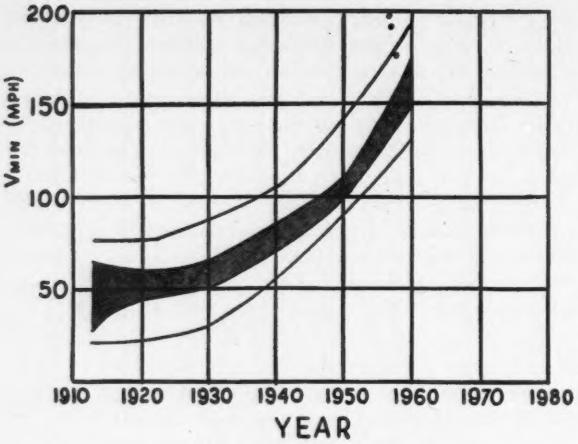

Figure 3
Minimum speed — all types

craft has been included for comparative purposes. It will be noted that the predicted curve for the supersonic transport agrees quite closely in rate-of-increase with that obtained for the bomber during the past ten years. The break occurring in the curve for the transport aircraft at about 500 mph and 1951 denotes the introduction of the Comet I aircraft.

Figure 3 is of particular interest because it shows the much lower, but nonetheless certain, rate-of-increase in approach speed for both the bomber and transport aircraft during the same period. The width of this curve results from including both types of aircraft. However, the lower edge of the curve more nearly represents the transport aircraft and the upper edge, the bomber.

Finally, Figure 4 shows the approach speed expressed as a percentage of the maximum speed taken for both types of aircraft. These curves are based on flight data, and the spread between the two is of particular interest. It will be observed that the transport aircraft's approach speed, although a higher percentage of its maximum speed, is actually lower in miles per hour than the approach speed of the bomber; while the latter's approach speed is a lower percentage of its maximum speed

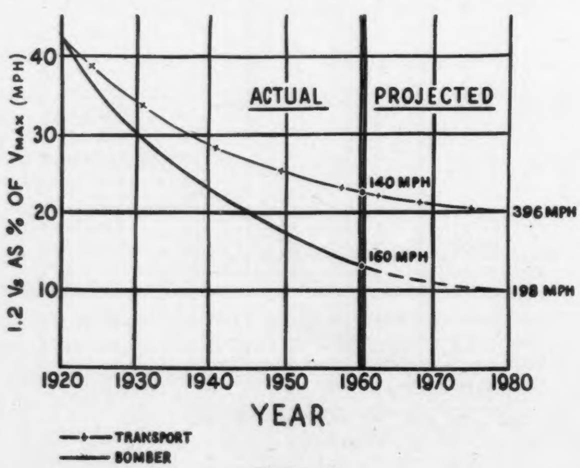

Figure 4
Minimum approach speed as percent of V_{max}

than is the former's. An extrapolation of these two curves to 1980, the time when it is predicted that both Mach 3.0 bombers and transports are likely to be available, indicates a substantial readjustment must be made in the curve for the transport aircraft. Otherwise, commercial airfields comprised of five-mile-long runways will be necessary to cope with the rather startling arrival of the supersonic transport.

Having had my jest through extrapolating factual data, it is necessary to reveal the obvious discrepancy in the prediction. The rather startling differences in approach speeds arise because the comparison was made between aircraft of subsonic and supersonic design characteristics. However, it is most unlikely that the supersonic transport's approach speed will be lower than that of the bomber because a portion of the transport aircraft's load cannot be disposed of prior to landing.

The significant factor which now emerges is that the supersonic transport will require an appreciably longer distance in which to land. Figure 5 shows the predicted ground roll and distance-to-stop from over 50 ft for probable supersonic transports at various landing weights

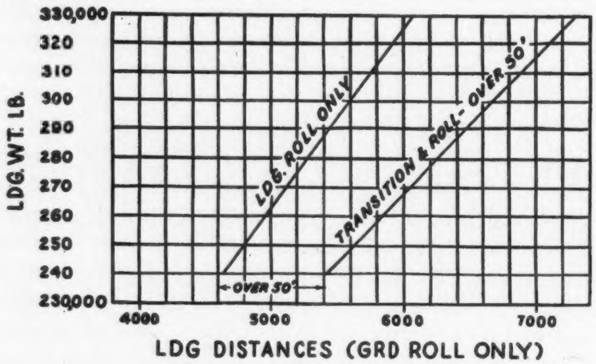

Figure 5
Aircraft landing distances
(ground roll only)

and at representative approach speeds. These curves are based upon ideal conditions of wind, weather and surface braking action.

An examination of the predicted mission profile for the Mach 3.0 transport indicates quite clearly the critical nature of its operation. The estimated performance characteristics of the aircraft are such that the imposition of present CAR regulations concerning reserve fuel requirements will likely prevent the attainment of acceptably low direct operating costs[5]. However, reductions in reserve fuel requirements must be achieved without sacrificing operational safety. This factor alone represents a major problem in an aircraft which loses approximately 11% of its en route cruise fuel if it encounters an unforeseen delay of 10 minutes by having to "hold" over a beacon.

If the time allowed for holding is to be reduced substantially, further improvements in air traffic control procedures will be required to maintain a high level of safety. In addition, better, faster and more accurate methods of forecasting weather conditions and improved, high speed, long range communications systems will be needed.

Improvements in these supporting systems are mandatory if the required utilization rates are to be achieved. The Mach 3.0 transport will have an annual productive capacity three times that of the DC-8, and approximately eight times the productive capacity of the current DC-7. Operating fleets will consist of considerably fewer aircraft than at present and non-adherence to precise scheduling, and lost or grounded aircraft, may well result in a bankrupt operator.

There are many additional, critical factors associated with the future of flight which cannot be commented upon at this time, because the scope of this paper and the time available to me are both limited. However, it must be noted that I have followed only the clearly defined edge of the performance and productivity curves in this presentation. It is essential, therefore, to observe that the over-all environment will be considerably cluttered by the vast fleet of present day reciprocating-engined and turbine-powered aircraft that will remain in operation for some time. Thus, the magnitude of the task confronting the terminal and en route traffic control agencies becomes more apparent.

What I have said to this point establishes the broad nature of the requirement for a vertical takeoff and landing capability. It has often been stated that aviation will never truly achieve its full potentialities until it can be carried out independently of the terrain or, in other words, we can land and takeoff vertically. We will not be able to exploit fully the advantages of air transport until we can do this. Such a capability promises to revolutionize the utilization of aircraft, particularly in the transport role.

VTOL AIRCRAFT

During the last three years it has been almost impossible to browse through a technical or semi-technical aeronautical publication without encountering some proposed version of VTOL aircraft. The pending availability of small, lightweight turbojet engines, of thrust-to-weight ratios approaching 10, has given the designer the means for providing the aircraft with a VTOL capability. The configurations proposed have ranged from the tail-sitter recently constructed and tested by Ryan Aeronautical Co., to the Short SC-1 which achieves vertical takeoff in the horizontal attitude on the thrust provided by engines mounted vertically within the fuselage. In addition, turbojet engines have been so mounted as to swivel through 90°, thus enabling the aircraft to takeoff vertically from a horizontal attitude.

The turboprop engine has also been used in VTOL aircraft. Aircraft using this powerplant range from the Convair tail-sitter, through the Ryan ducted slipstream and the recently tested Doak Company's wingtip mounted ducted fan variant to the Hiller tilt-wing aircraft. The latter three aircraft takeoff vertically from a horizontal attitude; however, the wingtip mounted ducted fans swivel through 90° to achieve VTO, transiiton and horizontal flight, whereas the ducted slipstream aircraft utilizes a combination of ground cushion effect together with the increase in lift derived from the slipstream passing over greatly enlarged slats and flaps. On the Hiller aircraft, the entire wing and engine installation tilt through 90° to achieve VTO, transition and forward flight.

All of the turbojet and turboprop configurations mentioned so far are noteworthy in one respect; they are all adaptations of the present airframe/engine design concept. Figure 6 has been provided to show the influence airframe design has exerted on the development of the engine. The engine was mounted in the position depicted in silhouette No. 1, Figure 6, for the obvious structural and cg reasons. As the streamlined, covered fuselage with its aft-mounted stabilizing and controlling surfaces was evolved, the engine was positioned in front, as depicted in silhouette No. 2. (There were, of course, certain aerodynamic benefits to be derived from locating the engine in this position). The attainment of minimum frontal-area drag from the fuselage argued against increased engine diameters, and silhouette No. 3 depicts the engine growing longitudinally with the requirement for increased power, while remaining within the maximum allowable cross-sectional area of the fuselage.

It was natural, therefore, that the turbojet engine should be located within the fuselage of the aircraft. The status of airframe design technology during the period when the turbojet engine was developed, and the wartime necessity for the immediate exploitation of this new source of power, precluded examination of alternative engine geometry or the installation of engines in other than existing airframe designs. This condition has prevailed to date and is evident in present and most future aircraft designs. Powerplant geometry continues to be guided by the pattern established in the past and the ultimate cargo and passenger air carrier might well be of the ballistic missile type, which might be depicted as an eighth silhouette on Figure 6. Indeed, this approach to a solution to our present problems does not suffer from a lack of proponents. A human pilot would not be necessary and some passengers will apparently accept anything once! It is believed, however, that the final and most suitable solution is to be found in the concept of a more completely integrated design.

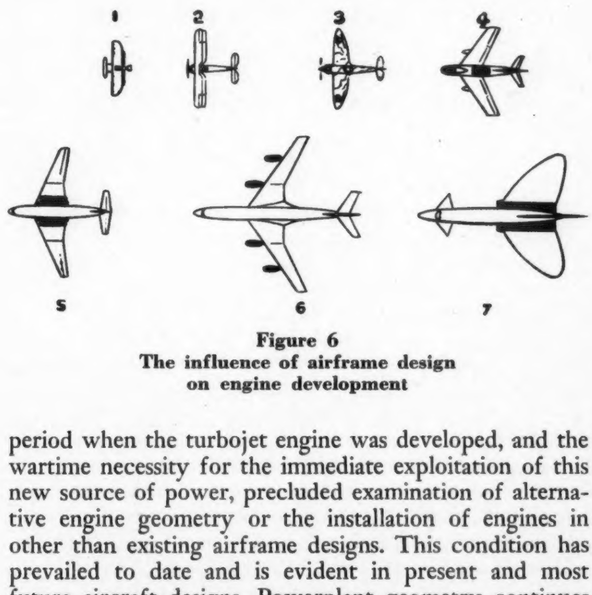

Figure 6
The influence of airframe design on engine development

CONCEPT OF COMPLETE DESIGN INTEGRATION

Today's aircraft consists of a wing which provides lift, a fuselage which, in addition to serving as the essential lever arm for the stabilizing and controlling surfaces, provides cubic capacity for the carriage of cargo and

passengers, and engines either appended to, or buried within, the fuselage or wing. This arrangement of the physical components does provide an acceptable degree of design integration because it has been functionally acceptable. There are historical reasons for designing the turbojet and turboprop powered VTOL aircraft in this manner; a most weighty one being that provided by the vast amount of theoretical and practical design data accumulated to date.

Present technology makes possible, however, a new concept of design; the circular shaped VTOL aircraft. This shape of aircraft most nearly approaches the concept of a completely integrated design. My belief that aircraft of this configuration will emerge is supported by various aeronautical research organizations and responsible and knowledgeable members of the aviation industry. In this regard, Sir Arnold Hall, in his presentation of the Twentieth Wright Brothers Lecture before the Institute of the Aeronautical Sciences on the 17th December, 1956, noted that interesting results were foreseen from unconventional approaches to the design of both the jet and the structure, the aim being a higher lift/drag ratio, less structure weight and high mobility in the direction of application of the thrust, without weight penalty – or, indeed with a reduction of weight[1].

A specific example of the development work being undertaken in this direction is provided by the following quotation from *Aviation Week*, dated the 9th March, 1959:

> "Another more revolutionary design development is being financed by the Army and Air Force jointly and is in progress at Avro Aircraft. This is the flying saucer which uses an annular jet to provide it with vertical rising ability. This annular jet theoretically and in small scale investigations has been shown to have the potential of increasing the available lift of an aircraft a hundred times or more when it is operating within ground effect. The lift increase realized by a conventional aircraft or helicopter is only about 15 to 25% when it enters ground effect. This type of aircraft also has a great speed potential in level flight."[6]

I shall not present a technical analysis of the circular configuration. However, it should be noted that such a planform apparently gives a higher gross weight to structure weight ratio than any other aerodynamic configuration. This can be easily confirmed by any second year university student of structures. It is rather ironical to note, in this regard, that the Square/Cube Law, devised by the renowned mathematician Prof. Simon Newcomb, and used by him to refute the possibility of flight in heavier-than-air craft, applies most ideally to this

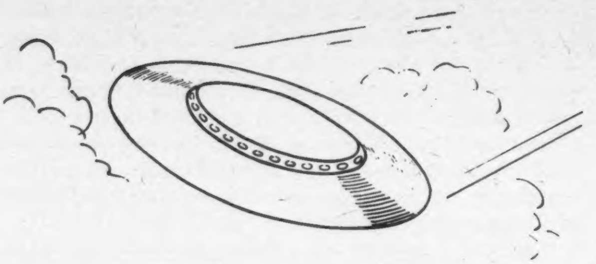

Figure 7
The shape of the future?

futuristic shape. Finally, the application of the annular jet and the advantages to be derived, indicated previously by theoretical and small scale investigations[7], have been partially confirmed by the recent flight of the Saunders Roe "Hovercraft".[8]

CONCLUSION

We have reached the stage where a change in the configuration and capabilities of the aircraft is essential. Its inherent flexibility, a characteristic upon which its utility and productivity are ultimately dependent and which is being lost because of the continuing necessity for longer and longer runways, must be restored. It is believed that the present level of technology combined with recent successful demonstrations of the aerodynamic principles involved clearly shows that this concept of the design of a VTOL transport aircraft is possible. The advantages to be derived are obvious. Perhaps Figure 7 depicts the shape of the future in air transportation.

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HALF MODEL TESTING IN WIND TUNNELS†

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SUMMARY

A review is given of the effects associated with half model technique in wind tunnel testing. These include tunnel wall boundary layer and gap between model and tunnel wall. Reflection plane configurations are considered. Some experimental data on comparison between full and half model tests are given.

INTRODUCTION

When testing symmetrical models in symmetrical flow conditions it is sufficient to consider the aerodynamic reactions on one-half of the configuration only, introducing a reflection plane as the longitudinal plane of symmetry, at which the normal velocity component is zero.

Half models have a number of advantages over full models, namely:

(i) Half models are cheaper and easier to manufacture than full models.

(ii) With half models mounted on the tunnel wall a static balance or an oscillatory test rig can be located outside the tunnel, resulting in a more efficient and simpler design as compared with internal balances and test rigs.

(iii) Pressure leads are easily led outside, resulting in relatively short leads to manometers or pressure transducers. Half models are particularly suitable for pressure measurements, especially on parts of the model not too close to the plane of symmetry.

(iv) For a given tunnel size a larger Reynolds number can be obtained with a half model than with a full model.

(v) Sting or strut interference effects are eliminated by a half model arrangement.

Force measurements on half models are limited to lift, drag and pitching moment at zero yaw angle. Rolling moment can also be measured but usually it is only of interest when asymmetrical features are introduced, such as aileron deflections. However, the reflection plane concept is not strictly valid in that case. The bending moment at wing root and the spanwise location of the aerodynamic centre of a half wing are normally obtained from pressure measurements; on a half model these measurements can be carried out directly.

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This report deals with true half models mainly. Many tests are carried out on outer wing panels, tail fins, etc; but in those cases the tunnel wall does not correspond to a plane of symmetry and cannot be considered as the correct reflection plane. Consequently, the test conditions are basically incorrect and the test results have to be considered with caution.

The use of half models introduces a number of interference effects which limit the reliability of test results. In the following, various interference effects are reviewed qualitatively and where possible experimental results are considered. The main effects considered are: subsonic downwash interference, tunnel wall boundary layer effects and the effect of gap between model and tunnel wall. A limited number of comparisons is given between full and half model test results.

LIST OF SYMBOLS

B	Tunnel height or breadth
b	Span or half-span of wing
C	Working section cross-sectional area
c	Wing chord
$\bar{c}$	Mean aerodynamic chord
C_D	Drag coefficient
C_{D_0}	Zero-lift drag coefficient
C_L	Lift coefficient
C_l	Rolling moment coefficient
C_{L_α}	Lift curve slope
C_m	Pitching moment coefficient
$C_{m_{\delta_e}}$	Elevator effectiveness parameter
$C_{m_{\dot\theta}}$	Damping in pitch derivative
C_N	Normal force coefficient
C_Q	$\frac{Q}{U_o\delta^* m}$ = suction coefficient
d	$\frac{\beta b}{c}$, leading edge parameter for delta wing
$E(k')$	Complete elliptic integral of second kind
h	Model height above tunnel wall, half bodies
h_1, h_2	Vortex generator dimensions
K	Circulation around aerofoil
$K(k')$	Complete elliptic integral of first kind
k	$\frac{s}{s+b}$ = gap parameter
k'	$\sqrt{1-k^2}$ = elliptic integral parameter
l	Local lift force
M	Mach number

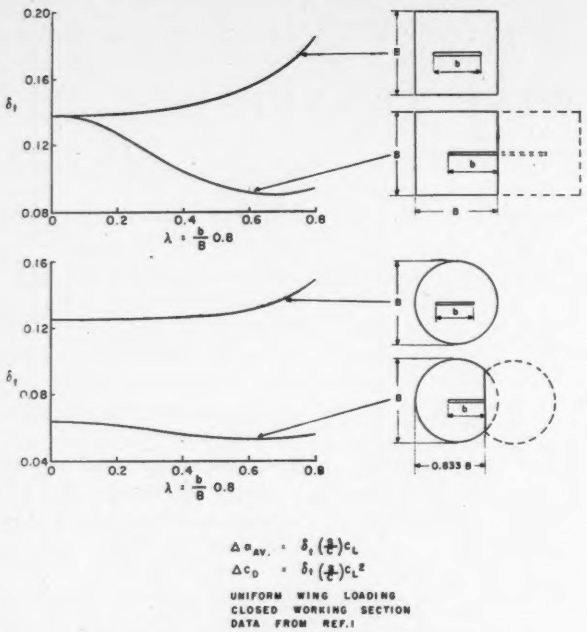


Figure 1
Downwash corrections for square and circular jets

m	Length of suction slot
p	Static pressure
p_o	Stagnation pressure
Q	Suction volume per unit of time
q	Dynamic pressure
Re	Reynolds number
S	Wing area
s	Gap width between model and tunnel wall
t	Wing thickness
U	Velocity (scalar)
V	Velocity vector
x	Streamwise coordinate
$x_{a.c.}$	Location of aerodynamic centre
y	Spanwise coordinate
z	Coordinate perpendicular to wing plane
α	Angle of attack
β	$\sqrt{M^2-1}$
Γ	Circulation
δ	Boundary layer thickness
δ_a	Aileron deflection angle
δ_e	Elevator deflection angle
δ_t	Downwash correction factor
δ^*	Boundary layer displacement thickness
ϵ	Fraction of δ, location of wall vortex
θ	Angle between V and free stream velocity
λ	$\frac{b}{B}$ = relative model span
$\omega_x, \omega_y, \omega_z$	Vorticity components in x, y and z direction

SUBSONIC DOWNWASH CORRECTIONS

The effect of tunnel boundaries on downwash of wings has been calculated for half wing models mounted on the wall in tunnels of various working section shapes. For a rectangular working section the corrections are equal to those for a full model mounted in a wind tunnel of double width. Calculations have been made by Kondo[1] for circular arc jets. Typical downwash corrections are shown in Figure 1 for a square and circular arc wind tunnel. The factor δ_t applies to the over-all corrections

$$\Delta\alpha = \delta_t \left(\frac{S}{C}\right) C_L \text{ and } \Delta C_D = \delta_t \left(\frac{S}{C}\right) C_L^2$$

for a uniform span loading of the wing. It is interesting to note that the correction factor δ_t is considerably smaller for half models than for full models having the same span to tunnel width ratio. In this figure the half model scale is twice the full model scale for the same value of $\lambda = b/B$.

The downwash correction for a half model in an octagonal working section was considered by Garner[2]. The upwash near the wall is increased because of the corner fillets; however, near the centre of the tunnel the effect of fillets is negligible. Thus, for instance, in testing ailerons the effect of fillets on rolling moment is very small.

Similar calculations were carried out for the almost elliptical working section of the NAE 6 ft × 10 ft wind tunnel[3]. The results are given in Figure 2. Because of balance location only the case of a half wing mounted on the tunnel floor was of interest. It was found that δ_t for a half model as shown differed very little from δ_t for rectangular working section.

The effect of sweep on downwash interference for a half wing appears to be only a few per cent of δ_t in a closed rectangular wind tunnel[4]. Methods are worked out in Reference 5 for semi-span swept back wings in closed circular and circular arc wind tunnels.

Half models in open jet circular and circular arc wind tunnels have been considered by Davidson and Rosenhead[6].

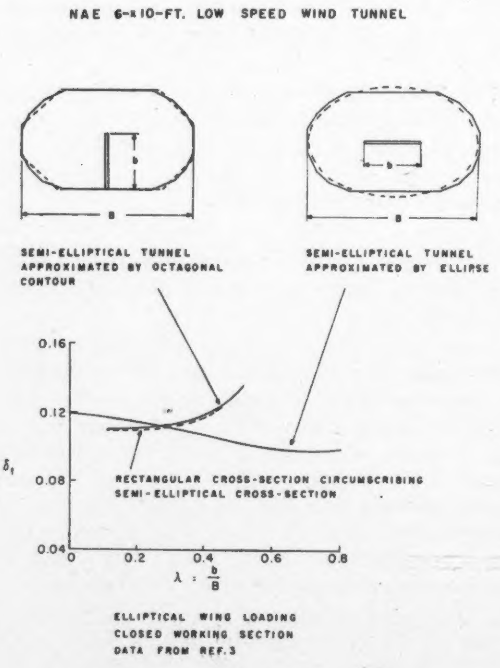


Figure 2
Downwash correction for a semi-elliptical wind tunnel

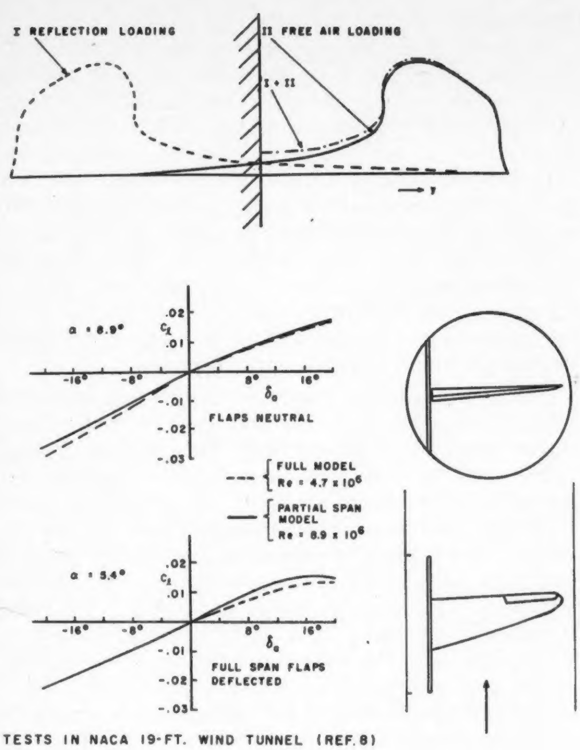


Figure 3
Reflection effect for asymmetrical wing loading

For symmetrical cases a spanwise downwash correction is generally not necessary, except for calculating rolling moment or for near stall conditions. Spanwise downwash corrections may also be required for hinge moment measurements. The downwash corrections then have to be determined for individual vortex elements, rather than for the rolled up vortices at some distance behind the wing. A similar procedure has to be followed for non-symmetrical loading on half models. For rectangular and circular wind tunnels these procedures have been worked out in References 7 and 8. In that case the tunnel wall or reflection plane is not a plane of symmetry.

The aerodynamic loading due to aileron deflection is illustrated by the top part of Figure 3, where the effect of reflection is given for the case of one aileron deflected. It is clear that an additional loading, especially near the wing root, is introduced by the reflection loading. Figure 3 also gives a comparison between full and half model results[8] on rolling moment. An even better agreement was obtained for angles of attack smaller than shown in Figure 3, and for larger angles of attack the full model gave lower rolling moment coefficient values. The last effect was attributed partly to differences in stalling characteristics, the full model having a smaller Reynolds number, and to some differences in models.

If only part of a half model (for instance outer wing panel with aileron) is tested, great care must be taken in correcting the data. In effect a reflection plane model of different aspect ratio is tested in that case. (See pages 205-216 of Reference 1.)

EFFECT OF TUNNEL WALL BOUNDARY LAYER

When a half model is mounted directly on the tunnel wall, the effect of tunnel wall boundary layer has to be considered. The tunnel wall boundary layer may change the flow pattern considerably. Wooltuft tests on a two-dimensional wing model, spanning the tunnel walls[9] indicated a highly disturbed region bounded by the tunnel wall and a line under 45° from the junction between tunnel wall and wing leading edge. Wooltuft tests with two different values of wall boundary layer thickness ($\delta/c = 0.10$ and 0.033) indicated that a thinner boundary layer does not necessarily produce a smaller disturbed region[10]. Presumably this confirms the trend of Figure 4. The disturbed area appeared sensitive to a small gap between the aerofoil and the tunnel wall. Even a small gap at the nose alone (< 0.5 mm over less than one-third of the chord length) introduced relatively large disturbances. Some improvement was obtained by introducing shims with slots between the aerofoil and wall. Presumably the influence of these slots is to accelerate the boundary layer air at the wing-wall junction, thus delaying separation and stall at the wing root. This is substantiated by tests on an aircraft model with slots near the wing-fuselage junction[11].

At supersonic speed the tunnel wall boundary layer effects are basically the same as at subsonic speed. There is an additional boundary layer shock wave interference effect. The shock wave near the model nose will be displaced compared with full model tests. However on a wing body combination at moderate supersonic speed the conical shock wave is relatively weak so that this

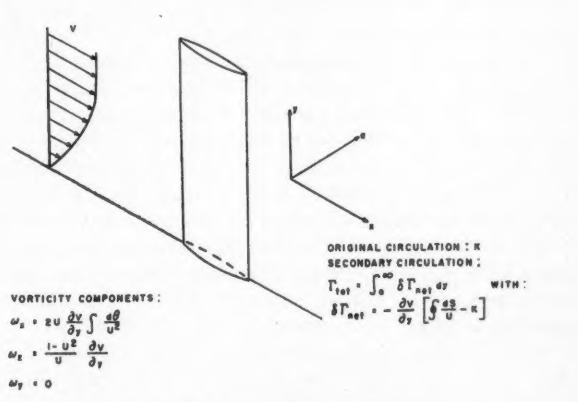


Figure 4
Secondary flow effects

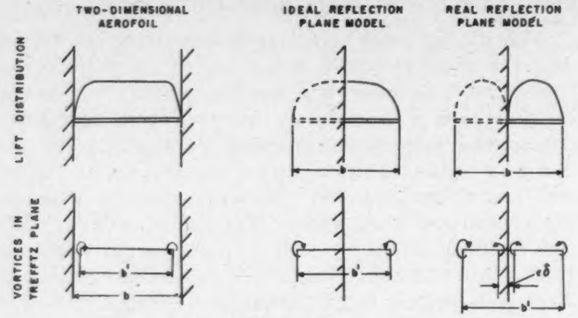


Figure 5

Vortices in trefftz plane due to tunnel wall boundary layer

effect may be unimportant. Reflected shock waves, originating from outboard model parts, such as engine pods, and trailing edge shock waves will be affected by the tunnel wall boundary layer. In all cases disturbances may propagate upstream through the boundary layer.

The influence of the velocity gradient in the tunnel wall boundary layer on the flow around an aerofoil protruding from a tunnel wall is known as secondary flow effect. The problem is illustrated in Figure 4. Secondary flow theory has been employed in References 12 and 13, while a simple geometric deduction of the same basic results is given in Reference 14. Figure 4 (after Reference 12) deals with an inviscid fluid, except for establishing the vorticity in the oncoming boundary layer. This procedure can be justified as long as the changes in shape of the vorticity tubes take place rapidly, similar to turbulence theory in contracting passages. As indicated by the upper half of Figure 4 the wing circulation K is decreased by secondary vorticity introduced as components in the x-direction as the boundary layer vorticity (in z-direction) travels along a curved path past the aerofoil. The energy in the induced velocities is a measure of the induced drag. For a bicuspid profile this was calculated by Hawthorne[12] (Figure 4). There appears to be a maximum effect of tunnel wall boundary layer near $\delta^*/c = 0.1$. A thin boundary layer with a strong vorticity may have the same effect as a thick boundary layer, having weaker vorticity tubes, but affecting a larger flow area.

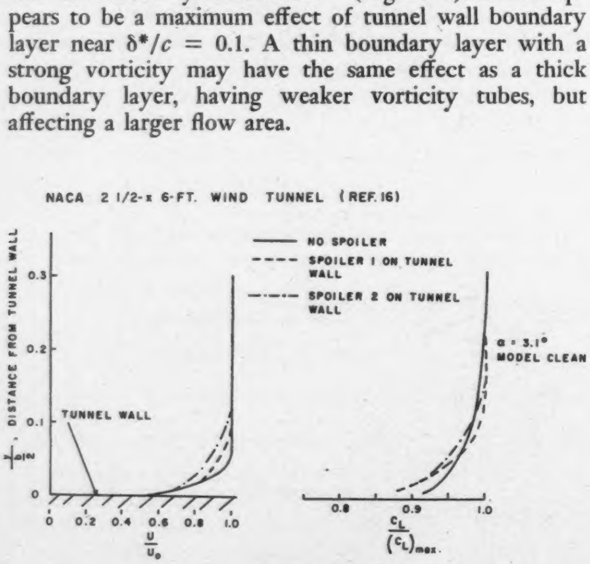


Figure 6

Lift distribution over a two-dimensional aerofoil

Effect on lift

Preston[15] noted that the effect of tunnel wall boundary layer on lift was to decrease the lift on an aerofoil close to the tunnel wall and, furthermore, the trailing vortices, resulting from that change in lift, would have an effect on the total lift distribution. In calculating this last effect individual vortices were considered; however, these trailing vortices are expected to roll up behind the aerofoil, as shown in Figure 5. Tests carried out at NACA[16] showed a much smaller effect than predicted by this theory. Some of these NACA results are given in Figure 6. Three different boundary layer profiles were used in this test. The effect on lift does not extend much beyond the actual boundary layer thickness.

Referring again to Figure 5 for the case of a half wing, it is clear that since the velocity at the wall is zero, and thus the lift is zero at wall, the rolled up trailing vortex near the wall must be equal in strength to the total circulation around the wing. This would introduce a very large effect on lift distribution. However the reflected vortex partly compensates for this effect. For simplicity only 'one cell' is shown in Figure 5 of the system of reflections, extending to infinity when there is more than one wall. The secondary vortex is $\frac{1}{2}\epsilon\delta$ from the tunnel wall. The estimated value of ϵ was 4/3 for two-dimensional models according to Carter and Cohen[17]. On the other hand an estimated[a] value of $\epsilon = 4$ was found from lift measurements on a swept back wing with circular reflection plate[11]. Clearly, a small value of ϵ introduces little effect on lift, the wall vortex then being cancelled almost entirely by its image.

Effect on drag

The reduction of lift due to wall vortices results in an induced drag. On the other hand a reduction in

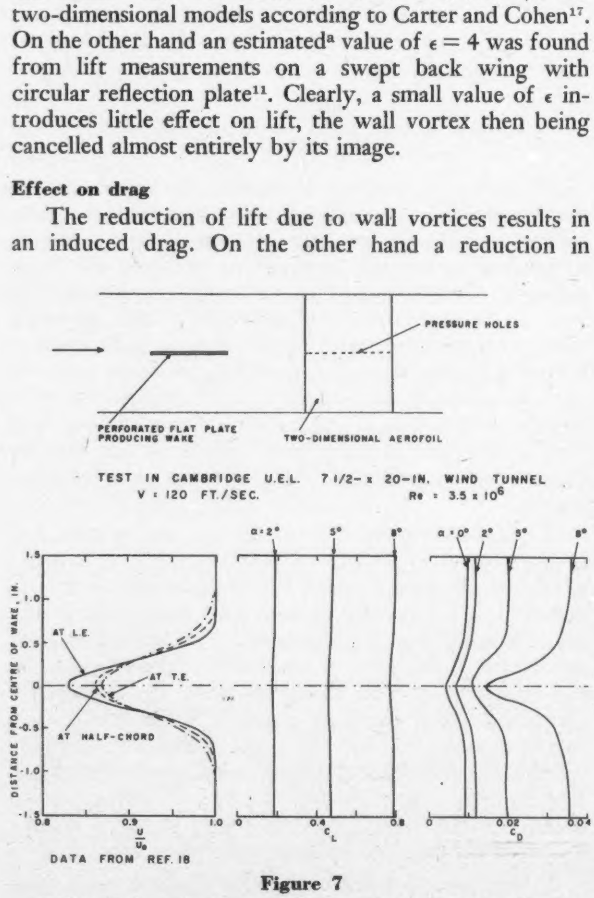


Figure 7

Lift and drag in stream with spanwise velocity gradient

[a]A value of $\epsilon = 20$, based on δ^* is reported in Reference 11. Assuming $\delta^*/\delta = \frac{1}{5}$, a value of $\epsilon = 4$ based on boundary layer thickness δ is obtained.

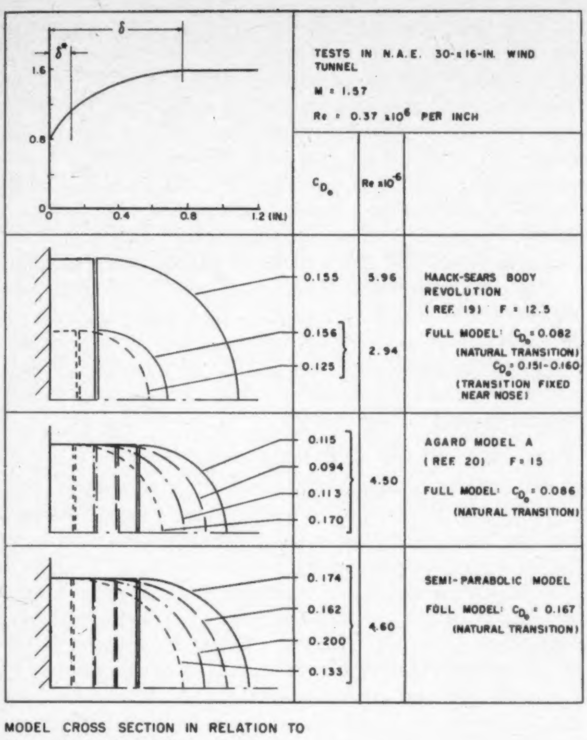


Figure 8
Effect of shim on half model drag (bodies of revolution)

velocity near the wall would result in a decreased local drag coefficient, based on free stream velocity. However increased turbulence over the wing or body will promote early boundary layer transition and possibly separation, resulting in a positive drag contribution.

There are no spanwise drag coefficient measurements available for a wing protruding from a tunnel wall. Mair[18] carried out pressure measurements on a two-dimensional aerofoil placed in the wake of a perforated plate. The arrangement and results are given in Figure 7. These tests are not directly comparable with a wing mounted on a tunnel wall, since the velocity at the centre of the wake was only 17% less than the free stream velocity. However it is interesting to note that an actual reduction occurred in the wake (for wing body combinations this is usually not the case). Here again the local forces on the aerofoil do not appear to be influenced much beyond the extent of the region of reduced velocity.

A series of half bodies of revolution was tested at NAE. Test results at $M = 1.57$ are given in Figure 8, where the body cross sections are drawn at the same scale as the boundary layer profile. The models were tested at various distances from the wall. For a Sears-Haack body the insertion of a boundary layer shim of ¼ in thickness resulted in a drag coefficient equal to that of a full model having a fully turbulent boundary layer[19]. A thinner boundary layer shim reduced the drag coefficient, but this was probably due to the reduced velocity region in which the model was located. In half model tests on AGARD model A[20], the drag coefficient

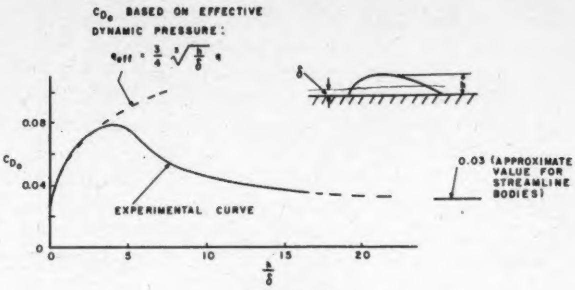


Figure 9
Drag of half bodies on wall[21]

went through a minimum as the distance to the wall was decreased (Figure 8). Separation effects may have been responsible for this effect. A model with a slightly different shape (bottom part of Figure 8) showed a decrease in drag coefficient for the thinnest shim (⅛ in). It may be concluded from these tests that, since model shape and distance to wall have such a large effect on drag coefficient, half body tests with a model radius of the order of the tunnel wall boundary layer thickness are unsuitable for absolute drag measurements.

The above conclusion is further substantiated by subsonic test results collected by Hoerner[21] and given in Figure 9. According to Hoerner all tests were carried out at Reynolds numbers above the critical and therefore the increase in drag near $h/\delta = 5$ was attributed to separation effects. A value of $h/\delta > 20$ appears to be required to produce the full model drag coefficient.

The pressure distribution on a half body of revolution was also measured at NAE[22]. The pressure distribution was compared with NACA full model results. A body of 1⅓ in maximum diameter with a ¼ in thick shim was found to give the correct pressure distribution. A larger body, 3½ in diameter, required a shim thickness between 0 and ¼ in. The boundary layer displacement thickness was about 0.2 in.

Comparing the radial pressure distribution on the above models showed a decrease of pressure ratio p/p_0 at the outer central meridian with increasing shim thickness, presumably due to deviation of streamlines from those of the axial symmetrical case[22].

An interesting arrangement for pressure measurements on a single wing surface is sketched in Figure 10 (from Reference 23), where the wing surface is made of an adjustable plate.

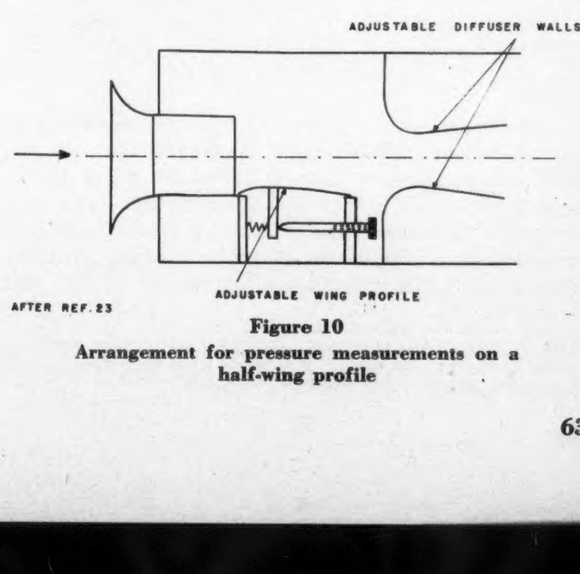


Figure 10
Arrangement for pressure measurements on a half-wing profile

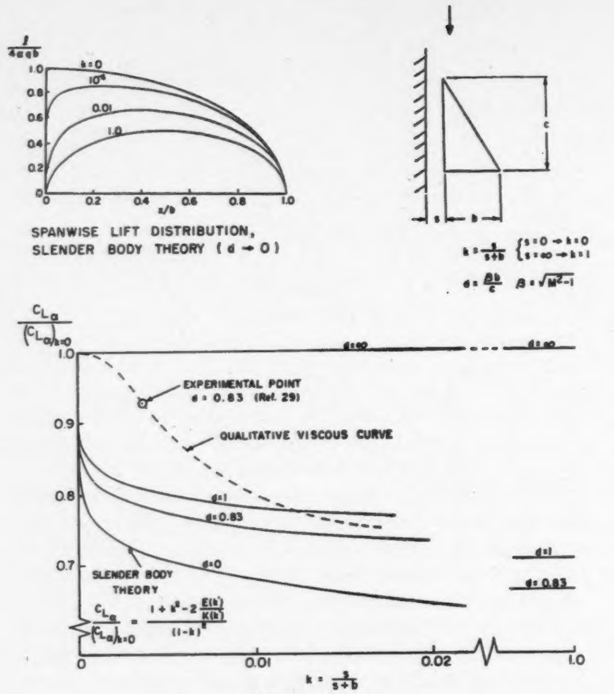


Figure 11
Lift loss through gap

EFFECT OF GAP BETWEEN MODEL AND TUNNEL WALL

In most cases there is a gap between model and tunnel wall introduced by the method of mounting. As mentioned previously in the section dealing with the Effect of Tunnel Wall Boundary Layer, the presence of shims with slots in a wing section near the tunnel wall may accelerate the boundary layer on the upper wing surface and thus delay separation and local stall. This would tend to increase the lift coefficient. However the effect of a gap between model and tunnel wall will be more generally a decrease in lift.

With slender body theory (two-dimensional potential cross flow of speed αU) the lift distribution on a small aspect ratio wing can be calculated for the case of a gap in the centre. Such theoretical results are given in the top part of Figure 11 (from Reference 24) where the spanwise lift distribution is given for a triangular wing, for various values of the gap parameter $k = s/(s + b)$. $k = 0$ corresponds to the case of no gap and $k = 1$ corresponds to the case of an infinitely wide gap. Even for very small gaps ($k = 10^{-6}$) the lift loss is considerable. For wings of large aspect ratio this effect will be much smaller[b].

The lower part of Figure 11 illustrates the effect of gap on lift curve slope for a number of values of the leading edge parameter $d = \beta b/c$. For $d = 0$ and $d = \infty$ these curves can be calculated theoretically. For $k = 1$ the points for intermediate values of d can be calculated and the rest of the curves ($k < 1$) is found by affine transformation of the known curve for $d = 0$ (see Reference 24).

[b]Gap leakage is also important on slender wing body combinations, such as missiles, where all movable wing controls introduce gaps between body and control surfaces[25].

The most serious limitation of the above theory is the assumption of inviscid flow. No theoretical results are available for viscous flow through a gap. If viscous effects were taken into account, it can be made plausible that the curves shown in the lower half of Figure 11 would have zero slope at $k = 0$ (Reference 24). Thus, qualitatively, curves as indicated by the dashed line in Figure 11 would be obtained. Only one experimental point is available for a triangular wing with $d = 0.83$ (see also Figure 14). However, the dashed line does suggest an almost negligible leakage effect for values of the gap parameter smaller than 0.001. This figure appears to be within reach of many existing balance arrangements.

For wing body combinations the lift loss due to gap is expected to be less than for wings alone, owing to the shielding effect of the body.

REFLECTION PLANE CONFIGURATIONS

In order to reduce or eliminate the tunnel wall boundary layer effect, various methods of model mounting have been used. Also methods are available to reduce the local boundary layer thickness.

The first possibility is to apply boundary layer suction ahead of the model. An interesting method of reducing the boundary layer thickness, suggested by W. J. Rainbird[26], is to mount two vortex generators (in V-shape) on the tunnel wall (Figure 12). The low energy air in the approaching boundary layer is partly moved off, ahead of the vortex generators, and partly drawn into the vortex associated with each vortex generator. Re-attachment takes place along lines of slightly larger sweep angle than of the vortex generators. The

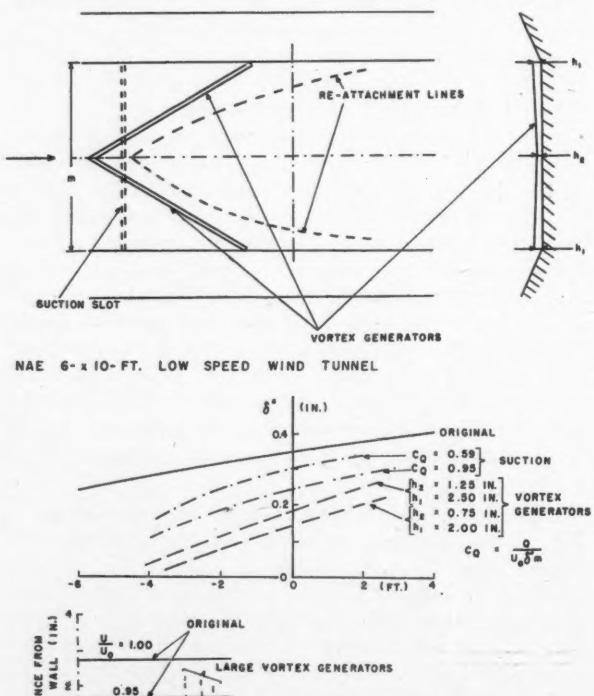


Figure 12
Reduction of tunnel wall boundary layer thickness

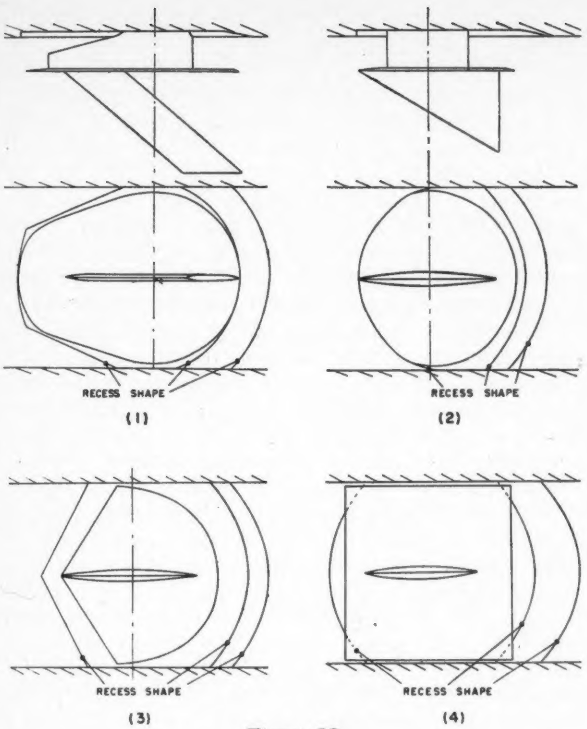


Figure 13
Reflection plane configurations[28]

air between the two re-attachment lines has full free stream total head pressure. Thus a new boundary layer is started at a short distance behind the vortex generator. Boundary layer measurements were carried out on such an arrangement (Figure 12, from Reference 27) for two sizes of vortex generators, consisting of tapered brass angle pieces. Figure 12 indicates a reduction of more than half of the displacement thickness at the tunnel centre. The lateral extent of the region of reduced boundary layer thickness is seen from the lower part of Figure 12. Comparative model tests are being carried out with these vortex generators installed.

Boundary layer suction through a slot ahead of the model was also attempted in the NAE 6 ft × 10 ft low speed tunnel. Figure 12 shows this to be a less effective means for reducing boundary layer thickness. The suction coefficient $C_Q = \frac{Q}{U_0 \delta^* m}$ should be close to one, so as to remove the boundary layer only. Suction through a carefully graded porous section closer to the model location would appear to be more effective. Such an arrangement could not be readily installed in the 6 ft × 10 ft wind tunnel.

Mounting a fence on a half wing, close to the tunnel wall, prevents the formation of a large disturbed area on the wing surface. Thus stall near the wing root will be delayed. Also the effect of pressure equalization through the gap between model and tunnel wall may be less.

The method of displacing the model from the tunnel wall and inserting a shim between model and wall has been mentioned in connection with drag tests (Figure 8).

The last two methods have the disadvantage of altering the shape of the model configuration. Also, with a shim the boundary layer influence, promoting early transition and non-uniform flow effects, is not entirely eliminated.

Boundary layer effects are largely eliminated by mounting the model on a reflection plate, displaced from the tunnel wall. The reflection plate can either be fixed with respect to the tunnel wall, the model being rotated with respect to the reflection plate, or the model can be mounted on the reflection plate, both rotating through the range of angles of attack. In the last case there will be no leakage between model and reflection plate, but balance readings have to be corrected for forces acting on the reflection plate.

Samples of various forms of reflection plates are illustrated in Figure 13. These reflection plates were designed for supersonic operation.

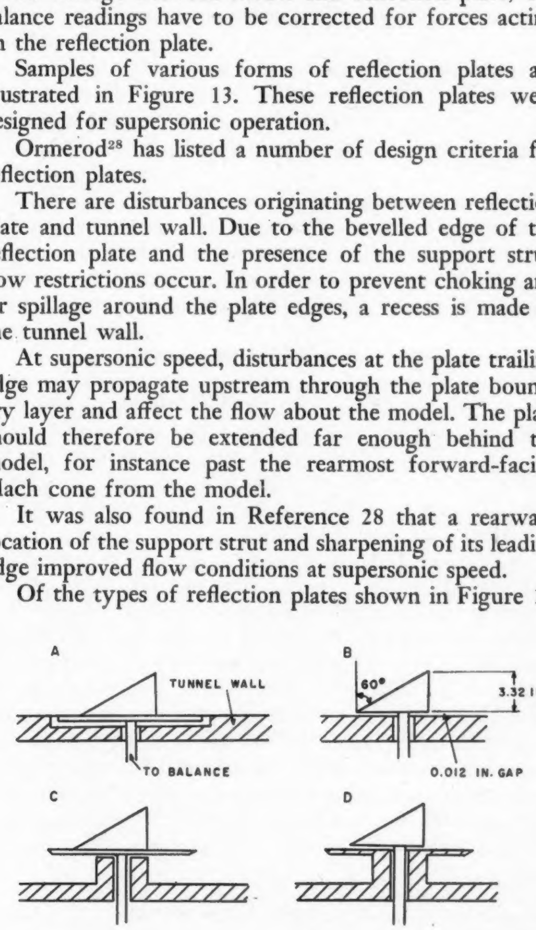
Ormerod[28] has listed a number of design criteria for reflection plates.

There are disturbances originating between reflection plate and tunnel wall. Due to the bevelled edge of the reflection plate and the presence of the support strut, flow restrictions occur. In order to prevent choking and air spillage around the plate edges, a recess is made in the tunnel wall.

At supersonic speed, disturbances at the plate trailing edge may propagate upstream through the plate boundary layer and affect the flow about the model. The plate should therefore be extended far enough behind the model, for instance past the rearmost forward-facing Mach cone from the model.

It was also found in Reference 28 that a rearward location of the support strut and sharpening of its leading edge improved flow conditions at supersonic speed.

Of the types of reflection plates shown in Figure 13,



APPROXIMATE RESULTS IN NAE 30- x 16- IN. W/T (REF. 29)
δ^* = 0.10 - 0.14 IN. CIRCULAR REFLECTION PLATE

METHOD OF MODEL MOUNTING	C_{L_α}	$\frac{\Delta x_{a.c.}}{\bar{c}}$
A	95 %	+ 0.02
B	88 %	< + 0.008
C	100 %	0
D	NOT TESTED	

Figure 14
Half model tests on small delta wings

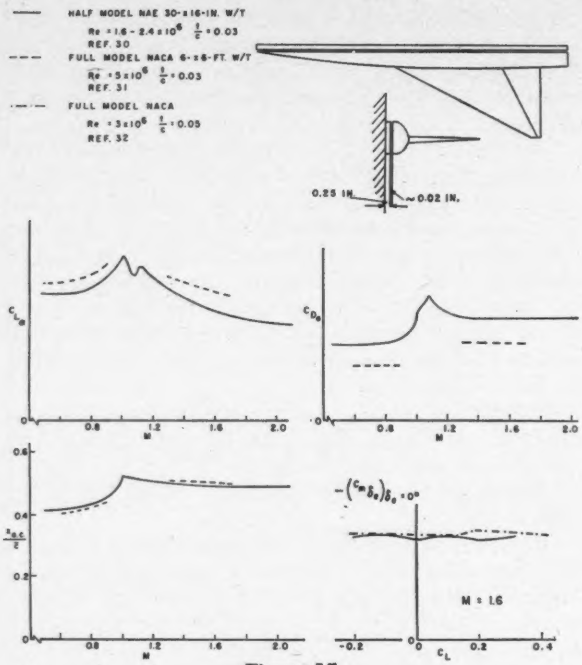


Figure 15
Delta wing body configuration

No. 3 was found to be the most promising. Tests on a plate spanning the tunnel (No. 4 in Figure 13) showed that for best results the model would have to be located behind the Mach line originating at the plate wall junction. This would result in a long reflection plate with a relatively thick boundary layer.

A series of tests on half delta wings was carried out in the NAE 30 in × 16 in wind tunnel[29]. Some of the results are summarized in Figure 14. These tests made it possible to separate the effects of gap and tunnel wall boundary layer. Taking mounting C as standard the tunnel wall boundary layer appeared to reduce the lift curve slope by 5% (method A). This would correspond to an area reduction equal to the boundary layer displacement thickness times root chord. However the tests were not all conclusive at supersonic speed. By comparing tests with method B and method A a reduction of 7% in lift curve slope was found owing to a gap of 0.012 in.

COMPARISON OF FULL AND HALF MODEL TEST RESULTS

There are few test results of full and half models available, allowing an assessment of half model technique. Some results are collected in Figures 15 to 18.

The delta wing body combination of Figure 15 was tested as a half model at NAE[30]. Comparison with NACA full model results indicated a 12% lower lift curve slope for the half model. The zero-lift drag was considerably higher for the half model. However, only little difference was found between full and half models for the location of aerodynamic centre and elevator effectiveness parameter. It is interesting to note that the general effect of Mach number was the same for both full and half models. A similar agreement is shown in Figures 17 and 18.

NACA full and half model test results, at subsonic speed, on delta wings and delta wing body configurations[33, 34, 35] are compared in Figure 16. The kink in the pitching moment curve for the delta wing (upper part of Figure 16) appeared to occur at the same lift coefficient, but was less pronounced for the half model.

Test results on Avro Arrow models (Figure 17) are interesting in that the same wind tunnel was used for both models. The same tendencies as previously noted are again distinguishable. The drag coefficient due to internal duct flow for the full model was not determined since the mass flow was not measured in that case.

The NACA results for a tailless aircraft configuration[36] show substantially the same differences in results (Figure 18) as those of Figure 17 for full and half models.

Little has been said about oscillating models, although the use of half model technique for oscillation tests offers great advantages from the experimental point of view. Some preliminary data on damping in pitch are given in Figure 19. The half model tests were carried out at NAE and are part of a more extensive comparison of various half model configurations[37]. Without going into details, however, it is noted that the half model results for two different axis positions are in good agreement with NACA full model results[38]. The variation of damping in pitch with Mach number, for a given axis position, is less than predicted by the theory of Reference 39, for both full and half models.

CONCLUSION

In reviewing the use of half model technique it becomes clear that very little information is available to estimate the specific interference effects. The main effects are known qualitatively, but few comparisons have been made between full and half models over a wide range of parameters involved.

A few general conclusions emerge from the present report:

(1) The tunnel wall boundary layer decreases the lift coefficient.

(2) The drag coefficient is generally increased by the tunnel wall boundary layer, although a reduction in zero lift drag is possible in principle.

(3) The tunnel wall boundary layer has the tendency to promote separation and stall near the wing root.

(4) For carrying out reliable drag measurements on half bodies the maximum body diameter should be at least an order larger than the tunnel wall boundary layer thickness.

(5) Even a small gap between model and tunnel wall reduces the lift coefficient markedly, but it should be possible to keep the gap small enough by careful balance and support design.

(6) Various means are available to reduce wall boundary layer influence: suction, vortex generators, wing fences and separate reflection plate mounting.

(7) Model parts relatively far from the tunnel wall or reflection plate are little affected by half model technique.

(8) Relative change of parameters can be measured satisfactorily on half models, such as: Mach number effect on lift, drag and pitching moment, control effectiveness parameters and possibly some dynamic characteristics.

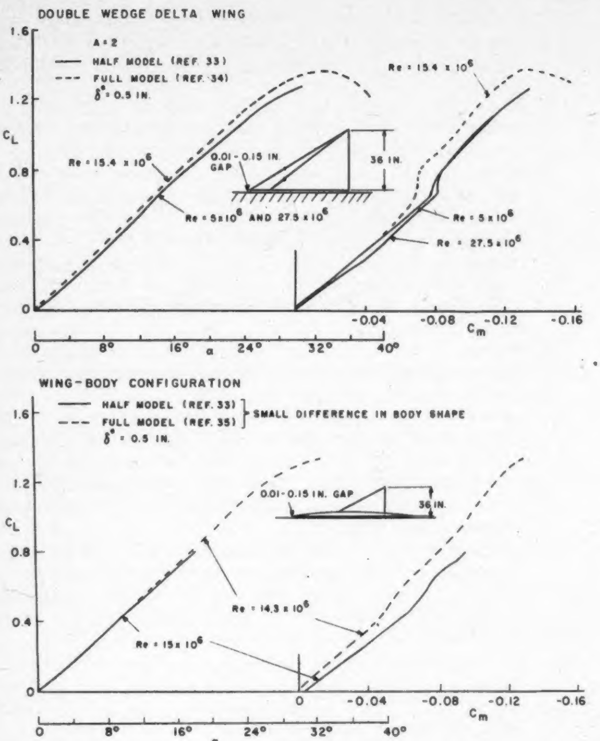


Figure 16
Low speed delta wing tests, NACA

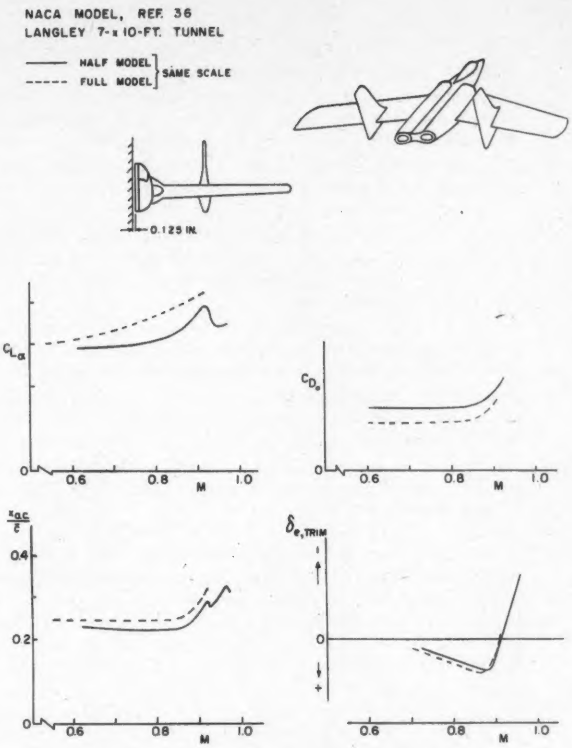


Figure 18
NACA tests on tailless aircraft model

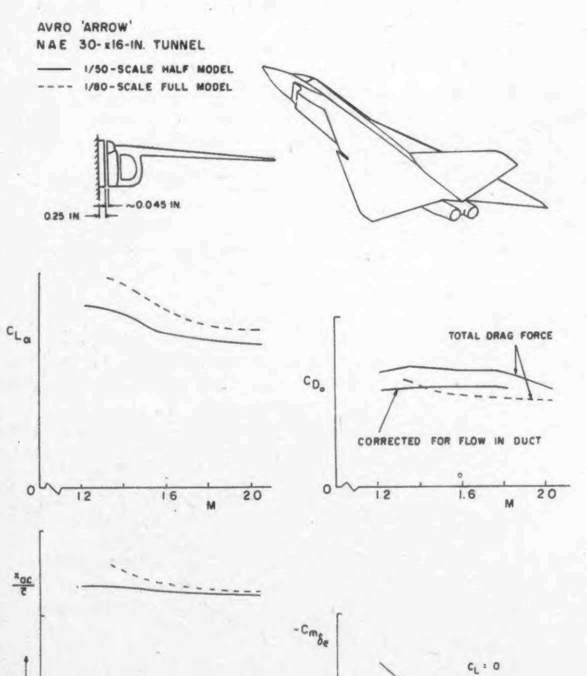


Figure 17
Tests on Avro Arrow aircraft model

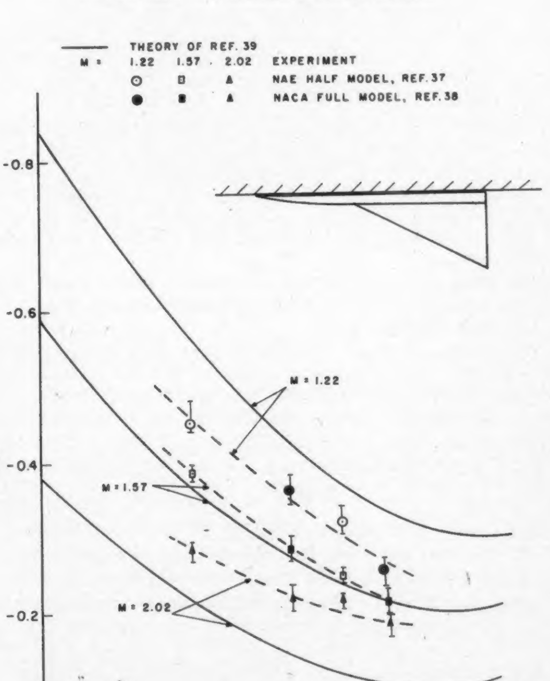


Figure 19
Damping in pitch derivative for full and half model

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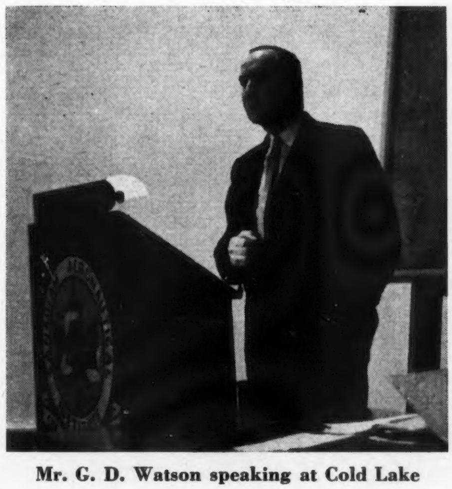
C.A.I. LOG

SECRETARY'S LETTER

January is not the best of months for travelling about the country but, from considerations of the Institute and Branch programmes, it seems to be the most suitable for my annual tour of the west. This year's tour, which occupied the week of the 18th to the 23rd January, was particularly successful. For the first time the President came too and we were able to attend Branch meetings at all the Branches we visited, Edmonton, Cold Lake, Vancouver, Calgary and Winnipeg.

The National Programmes Committee had arranged for Mr. G. D. Watson of the Defence Research Board to speak to the Branches at Edmonton, Cold Lake and Winnipeg, and the President and I naturally planned our tour accordingly. At each of these Branches Mr. Watson gave an excellent paper on the Scientific Exploration of Space; the Branch Secretaries will no doubt report on these meetings and I have no intention of stealing their thunder.



Mr. G. D. Watson speaking at Cold Lake

EDMONTON

The visit to Edmonton was the least satisfactory because unfortunately the President was delayed in Ottawa and missed the main part of the Branch meeting. However he followed on a later plane and arrived in time to put in an appearance before everyone had gone home, and he was able to meet some of the members and, at a sort of reassembly, to talk to them about the current affairs of the Institute.

The President addressing the members at Edmonton

Another misfortune about our visit to Edmonton was the absence of F/L Weinstein, the Branch Chairman. We missed him and hope that his duties will not keep him away from the Mid-season Meeting in February. Incidentally we stayed at the Kingsway Motor Hotel where the Mid-season Meeting will be held and took the opportunity to have a look at the facilities and to do some planning with the Branch Officers concerned. Everything is taking shape nicely and I am sure that we can count on the traditional western hospitality; it is always in the air in that part of the world.

Before we left Edmonton on the Tuesday, the President, Mr. Watson and I visited Northwest Industries, where Mr. Young, the Past Chairman, had kindly arranged a meeting of the Branch Executive Committee. With Mr. van Horne, the Vice-Chairman, presiding, we had a very useful discussion of Institute and Branch problems, great and small.

COLD LAKE

Not the least of our adventures was our journey from Edmonton to Cold Lake, and back again the next day, in a Cessna 172. Perhaps the incident was more unusual than adventurous; none of the three of us had been in this type of aircraft before and all of the three of us, with W/C Hoye as the pilot, were — one might say — a "press fit". There was also some inconsistency between our loaded cg and the position of the main wheels, with a consequent tendency to tail-sitting. But it flew very nicely. F/L Lumsdaine was our pilot on the return journey. It is not every day that one has the honour of being flown over the snowy wastes of northern Alberta by Councillors of the Institute. (W/C Hoye retired from the Council last June and F/L Lumsdaine took his place.) The aircraft was chartered from the Edmonton Flying Club.

We all enjoyed our visit to Cold Lake immensely. They look after you very well there and the Branch, though rather small, is very much alive. We had a first class meeting to hear Mr. Watson's paper, with a lot of good discussion — the President spoke to them briefly at the beginning — and afterwards the President and I attended a meeting of their Executive Committee. There is no doubt that the Branch is making a real contribution

Mr. Panton concludes his introduction of the President

to the professional life of this remarkable and isolated community. Mr. Panton, the Branch Chairman, has arranged that a good many members serve on the various Branch Committees and one gets the impression that there are very few members of the Branch who are not actively and enthusiastically engaged in some phase of its work.

We were all sorry when our visit was over.

VANCOUVER

Mr. Watson left us at Edmonton, and the President and I went on to Vancouver. Here we were met by the Branch Chairman, Mr. Hutton, and his Secretary, Mr. Whiskin, who took us to our hotel. They had arranged for us to have a large room, in which a table and chairs had been set up, and in due course the other members of the Branch Executive Committee arrived and we had a meeting. The Vancouver Branch has always contributed very effectively to the development of the Institute and its successive Executive Committees have done a great

Mr. Worden, Chairman of the Panel, speaking at Vancouver

deal of constructive thinking, which has been invaluable. I mean no reflection on the other Branches when I say that I am always struck by Vancouver's sense of the national character of the Institute; they act and think as one of the nine components of the Institute's structure and they seem to recognize clearly that the Institute depends on the nine Branches and not the Branches on the Institute. Consequently I have always found meetings with their Executive Committee very fruitful of ideas and I am sure that on this occasion the President shared this impression.

As our meeting ended we were joined by the representatives of Rolls-Royce, Pratt & Whitney and General Electric who were to entertain us later with a Panel Discussion on By-Pass and Fan Engines. The papers were cleared away; the ashtrays emptied; and the table was laid for dinner. And a good dinner it proved to be.

After dinner we proceeded to the RCAF Officers' Mess, Sea Island, for the Branch meeting. It is not often that you hear Programmes Chairmen grumbling about a good turn-out, but this time, every time I ran across my old friend S/L Falls, he was muttering profanities about not enough chairs. It was a good show. The President said a few words before the Panel Discussion started (I am not sure that Panel Discussion is quite the right expression) and we ended up with a good barrage of questions from the floor. Altogether it was a most successful meeting and proof, if any were needed, that the Vancouver Branch is very much a going concern.

CALGARY

On the Thursday, we visited the Calgary Branch. Except for speaking briefly to hastily gathered and, I felt, very "captive" audiences of students at the Provincial Institute of Technology and Art, before the Branch was

The President addressing the dinner meeting at Calgary

formally established, I had never attended a meeting in Calgary and I was looking forward to the experience.

I was not disappointed; in fact I was very pleasantly surprised at the vigour of the Branch and the way things had been organized in the short time the Branch has been in existence. The attendance at the Dinner Meeting was very creditable — we filled the room — and after dinner we had what I thought was rather a remarkable session. Firstly the President addressed the Branch and then Mr. Zmurchyk, the Branch Chairman, handed over the proceedings to Mr. Ryning and the technical part of the meeting began. The guest speaker was Mr. R. McCormack of Canadian Pratt & Whitney, who started by giving us a short review of the P & W family of gas turbine engines. Then he sat down and invited the audience to fire questions at him. There followed one of the best discussions I have heard. It was quite informal but questions came in from all quarters and Mr. McCormack handled them very well. It went on a long time.

When this exhilarating business was over, the President and I withdrew to a corner with the Branch Executive Committee and talked about Institute and Branch problems until a late hour.

WINNIPEG

Our last visit was to Winnipeg on the Friday. Here we caught up with Mr. Watson again and, though Friday night is not good for meetings, the turn-out was good; again we filled the room at the dinner which preceded Mr. Watson's talk. Mr. Torell, the Branch Chairman, presided in his usual cheerful manner and the Branch gave us a very warm welcome. The President again spoke to them briefly before Mr. Watson began.

We managed to talk a little CAI business with Mr. Torell and Mr. Davidson after the meeting, but by this time we were getting rather tired and it was difficult to resist the distractions of more congenial gossip with the many old friends who gathered round.

We left Winnipeg in the small hours of Saturday morning and were back in Ottawa by 10 o'clock.

THE PRESIDENT'S TOUR

This was the first time that a President of the Institute has visited all the western Branches and, in my view, the tour was very well worth while. I hope that it becomes a regular feature of our programme. We plan to visit the other Branches before the season is over.

We were very fortunate in being able to attend Branch meetings everywhere we went; for such meetings give a very much better impression of the health and spirit of the Branches than one can ever obtain from conversations with the Executive Committees. Moreover they give the President and the members an opportunity to meet each other and to talk things over.

The Branches differ surprisingly. Each has developed its own characteristics and each in its own way is serving its members well. There are difficulties, of course, and one or two quite serious depressions in the generally high plateau of keenness and activity. It occurred to us that closer co-operation between the Branches might be helpful. For example one Branch might ask another to furnish a speaker now and then; for there is plenty of talent in each Branch, though inclined to be without honour in its own country. I mentioned that the Vancouver Branch seemed to have a more highly developed sense of its place in the Institute than some of the others; this almost subconscious appreciation that there is no Institute apart from the Branches, that each Branch has one-ninth responsibility for everything that the Institute does, the Journal, the major Meetings and so on, and almost all the responsibility for its own programme — this is democracy and herein lies the Institute's strength.

The meeting in Winnipeg

OUR HOSTS

In previous years, in writing these reports of my tours, I have always found it difficult to avoid mentioning the names of the many friends encountered along the way. The same difficulty besets me now. This letter could turn into a veritable List of Members if I were to yield to the temptation. To say how good it was to meet you and you and you again, and to thank you all for your very warm welcomes, would comfortably fill this issue of the Journal. I am sure that the President joins me in expressing our most sincere thanks to everybody; this means you.

We hope to see many of you again at the Mid-season Meeting in Edmonton.

P.S. I apologize for the photos; they were strictly experimental. But my fumblings with the camera evoked so much interest that I thought you would like to see the results.

BRANCHES

SURVEY OF THE BRANCHES

Cold Lake

By J. B. Panton
Chairman

Early in 1956 three or four members of the Canadian Aeronautical Institute, formerly associated with the Toronto and Ottawa Branches, proposed, to interested personnel, that a local Branch of the CAI be formed at RCAF Station Cold Lake. Accordingly, at a meeting held in March, 1956, an Interim Executive was elected, Branch Regulations were drawn up and a lengthy discussion was held regarding the foreseeable problems and difficulties which might develop in a Branch in such an isolated area. At first the membership consisted mainly of service and civilian personnel attached to the Central Experimental and Proving Establishment. However, as regular meetings were held the interest grew and the membership rapidly expanded as personnel from the various other units on the station applied for and obtained their memberships. The infectious enthusiasm generated by the various hard working Committees culminated in the official recognition of the Branch by the Council in August, 1956. The Interim Committees were unanimously elected as the official Branch Committees and before the end of the first year of operation through the efforts of these Committees the membership had grown to 52 – 35 of these members had joined the CAI at Cold Lake.

One of the major difficulties of the Cold Lake Branch is keeping the membership at a certain level. Considering a three year tour of duty as average it can be seen that one-third of the members can be expected to leave each year. Because of this "non-permanent" status of personnel on the station a continuous campaign for new members is the only way of assuring replacement members. Although we are small in numbers compared with other Branches, nevertheless, because of the close association with aeronautics of all personnel on the station, the members in particular have shown a keen interest in the many and varied lectures and thus the successful operation of the Branch.

Excellent local arrangements for meetings are available on the station and full use of the Ground Instruction School theatre is made since it has both still and movie projectors available should they be required. Since all but a few of the members live on the station, transportation and parking are the least of our problems. However, because of so many other conflicting station activities it is difficult to have any particular set day or date for meetings so arrangements are reasonably flexible. Generally speaking the meetings are held the second Monday of the month. Accommodation for visitors, guest speakers, etc is of a high standard and very reasonable in cost. Therefore the expenses of the Branch are kept to a minimum and the annual grant from CAI headquarters is adequate to cover operating expenses.

During the first few years of operation the initial fears that, due to the semi-isolation of the station, interesting speakers would not be available soon proved unfounded. Not only have we been fortunate to have many interesting speakers visit the station and talk on a large variety of subjects but also it was quickly learned that with the wide diversification of interests and jobs of personnel on the station many well qualified local people were available and they too have given informative lectures on very up-to-date topics. At present, however, it is becoming increasingly difficult to obtain speakers from the station because most of the subjects have been covered and there seems to be a certain amount of apathy which perhaps could be traced to the recent upheavals in the aircraft industry in general. Therefore any assistance from the National Programmes Committee is always most welcome.

It is earnestly hoped that the future of the Cold Lake Branch will be able to meet the intent of the Institute, namely, to advance the art, science and engineering related to aeronautics.

Cold Lake Branch Executive
(Standing l to r): Mr. W. S. Bacon, WO1 G. A. Feltmate and F/O J. J. Francis
(Sitting l to r): Mr. J. B. Panton and S/L R. E. Zwicker
Inset: (l) F/L L. S. Lumsdaine and (r) S/L A. E. Kelly

Edmonton

By F/L K. Weinstein
Chairman

Prior to the inaugural meeting of the Edmonton Branch of the CAI on the 9th January, 1956, there had been a few informal gatherings of Edmonton members of the RAeS and the IAS, culminating in a dinner in honour of the

Secretary of the RAeS, Dr. Ballantyne, in July of 1955. Thus, the ball was set rolling.

The Branch has been in existence for a little under 4 years now which probably makes it one of the youngest of the Institute's children. It was a sturdy infant at birth, and its activities since have been numerous and diversified, but the child's growth has been stunted by the lack of a sufficiently large local segment of population connected with aviation from which to feed it; and the absence of a strong Northern Albertan aircraft industry — with the exception of Northwest Industries Limited — has made it a bit of an orphan.

Some 35 lecture meetings have been held to date. They have covered a wide cross-section of interests, from papers on the more common design aspects ("Development Trends in Gas Turbine Engines", to mention but one example) to talks on some less usual and seldom heard-of problems of present-day design ("Acoustics and the DC-8") and to glimpses of the 1970's ("Application of Nuclear Power to Aircraft"). They have included papers on present day operations ("TCA Viscount Operation") and on future operational planning ("The Introduction of Jet Aircraft into Airline Operations"); papers on electronics ("Limitations of Radar"), on DOT activities ("Aircraft Accident Investigation"), and on helicopters and VTOL Aircraft ("Engines for Vertical Takeoff"); on bush flying both in Canada ("Reminiscences of Northern Flying") and abroad ("Wings over Africa"); and on a host of others. Local speakers have presented to us papers on cold weather proving methods and results (both generally and on specific types); on current aircraft and systems testing methods; on radar problems; on aviation petroleum products; on gliding and International Gliding Meets; and so forth. Some very excellent films have been shown over the years, too.

The 1958-59 season, in particular, brought to our Branch lecturers and papers of a quality and variety of which a very much larger society, situated in a metropolis amidst a flourishing industry, might well have been proud. For this, no words of praise can do adequate justice to the work of our then Programmes Chairman.

Yet, in spite of what the Branch has had to offer, our membership has remained stagnant, with fluctuations around 50-to-70-members-mark. Why?

I think there can be no doubt about the answer. In a city of the size and the industrial make-up of Edmonton, the number of people eligible for a grade of membership of the CAI is of necessity small. The only relatively big employer in the aviation industry field here is Northwest Industries who have given this Branch invaluable support throughout the years. Of the airlines, Pacific Western alone maintains a large base here, but those amongst airline employees who are eligible *and* feel the urge to join, are probably a mere fraction of the total number. Fairly recently, the University of Alberta has added aeronautical engineering to its curriculum; time will tell how this will affect the growth of the Branch. Finally, concerning the RCAF in the area, experience has shown that support in numbers can only be expected from the more engineering, or test-flying, minded people serving with the Technical Services Detachment at NWI and with the Central Experimental and Proving Establishment which maintains its Climatic Test Detachment at Namao, a few miles from town. There are also the competing attractions of the city; for instance, we still have not found an evening of the week most convenient to a significant majority of the members and hence are now trying to alternate our monthly lecture nights between Tuesdays and Wednesdays. If one then stops to consider that almost all of our lecturers are from out-of-town and often travel considerable distances to address us, and that therefore the lecture night also has to suit the lecturer, one begins to sympathize with the Programmes Chairman and his task of arranging a successful meeting with a reasonably sized audience.

Given these local problems, what can a small Branch like ours do about it? How can it raise its membership, its attendance at meetings, and, with that, how can it improve its finances?

We considered two schemes. The first one was to provide for "Branch Members" who were *not* members of the Institute but purely members of the Branch; who need *not* be eligible for membership of the Institute and therefore could be attracted from a much larger pool of local population; and whose dues would go to the Branch only and would be much lower than the membership dues of the Institute. That scheme was not approved by the Council.

The second scheme is one we have just passed and introduced. It is much too early to tell whether or not it will help us out of our difficulties, and whether it will be of value to other Branches in similar circumstances. The scheme introduces a "Guest Card" which enables the holder to attend all the lectures of a season at moderate cost. Individuals eligible to become members of of the CAI (the word 'members' being used loosely to mean any grade of membership) will be able to purchase a "Guest Card" for only one season after which they must make up their minds and either apply for CAI membership or drop out; but individuals not eligible to join the CAI will be able to renew their "Guest Card" year after year and thus virtually become non-voting members of our Branch, without, though, being able to call themselves "Branch Members". With bated breath, we are hoping . . .

Has all this sounded too much like a tale of woe? In a good many other respects we have been fortunate. Through the courtesy and assistance of 700 Wing, RCAF Association, we have been allowed to use their premises for our meetings, in continuation of the practice established when the building was an Auxiliary Squadron Officers' Mess. This is an ideal place for us; it is located at the Edmonton Municipal Airport; it has large and small rooms; it has a bar; and we are not (barring the barley-bree from the bar) being charged for the use of it.

Edmonton Branch Executive
(l to r): Mr. C. B. Falconar (recently resigned), Mr. W. C. W. Mason, W/C J. G. Portlock, F/L K. Weinstein, Mr. R. W. Van Horne and Mr. C. C. Young. (F/O A. J. Robinson is missing from photograph)

NEWS

Halifax-Dartmouth

Reported by J. Milman

December Meeting

The December meeting of the Branch was held in the cinema of the Chief Petty Officers' Mess, HMCS Shearwater, on Wednesday, December 16, 1959. The Branch Chairman, Mr. R. Wallworth, was in the chair. The talk for the evening was given by Mr. F. T. Dryden of Rolls-Royce of Canada Limited on Jet Engines.

Mr. Dryden opened by outlining the theory of jet propulsion and showed how, at high speeds, it is more efficient than piston engines. The principle of jet propulsion was then illustrated by the showing of a film entitled "Application of Jet Propulsion to Vertical Takeoff Illustrated by the Flying Bedstead". Mr. Dryden completed his talk by comparing the straight turbojet engine with the bypass turbojet and discussed the relative merits of the two types.

Toronto

Reported by C. F. de Jersey

December Meeting

The fourth meeting of the Toronto Branch season was held in the De Havilland Aircraft Company Cafeteria on Wednesday, 15th December.

The Vice-Chairman, Mr. C. H. Bottoms, welcomed the audience of 97 which included 19 guests, and introduced the speaker, Mr. F. T. Moore, TCA Project Engineer for the DC-8 aircraft.

Mr. Moore apologized for the absence of Mr. J. T. Dyment who had accepted our invitation to speak on the DC-8, but due to urgent business had been unable to make the trip.

In opening, the speaker remarked that since the DC-8 was his favourite aeroplane, he had experienced great difficulty in condensing his material into a reasonable time limit. As it happened, he talked for an hour and a half, and was bombarded with questions for a further forty-five minutes before Mr. Bottoms called a halt – to the disappointment of the audience and the relief of the barman.

Mr. Moore divided his paper into three sections, i.e., Technical Details, Operations and Service. Commencing the technical portion he reminded his audience that this 300,000 lb monster's length was greater than Orville Wright's first flight!

In describing the DC-8, Mr. Moore pointed out some unusual features, such as the extensive use of titanium in the construction, 30° sweep back instead of the more orthodox 35°, a new slot installation improving the runway takeoff by some 16%, triple windows for additional passenger safety, the ac electrical system, introduced because of its low weight, reliability and increased power potential and, finally, provision of facilities for a spare engine to be carried between No. 2 nacelle and the fuselage.

In dealing with operations, Mr. Moore emphasized that at present only Delta and United Airlines were operating this aircraft, so that no real information was as yet available, but that, of course, their slogan would be ***high, fast and often***, to obtain maximum utilization.

The aircraft would be maintained by the progressive maintenance concept, wherein the overhaul of the aircraft is completed within 2,400 hours by a programme of 12 overhauls spaced at 200 hour intervals. By this method minimum physical breakdown is obtained allowing maximum utilization consistent with aircraft integrity.

Line servicing would obviously present problems, since 50% more runway is required for the DC-8 than for the Constellation, 152,000 lbs of fuel are carried representing two complete railway cars of fuel, and the handling of 80% more passengers and baggage than at present, will require reorganization of our terminal facilities.

Mr. R. McIntyre of De Havilland thanked Mr. Moore, both for his excellent paper and for the two very fine test programme films he had provided. In closing, Mr. McIntyre stated that we were all sorry Mr. Dyment had not been able to come to Toronto, but was to be congratulated for having provided such an excellent substitute.

In closing, Mr. Bottoms reminded the audience that Mr. Freudenthal of Columbia University was to address the Branch on January 14th, 1960, again in the De Havilland Aircraft Company Cafeteria.

Vancouver

Reported by J. W. Whiskin

December Meeting

The meeting was held in the RCAF Officers' Mess, Sea Island, at 8 pm on the 16th December. Sixty-one members and guests attended. This was a "Ladies Night"; members were invited to bring their wives and judging by the number of ladies attending it was a very popular idea.

The Vice-Chairman, Mr. F. L. Hartley, conducted a short business session for Mr. Hutton, the Branch Chairman, who was unable to be present. Mr. Hartley introduced Dr. G. M. Shrum, Dean of the Faculty of Graduate Studies, UBC, whose subject, "Science and the Space Age", served as a spring-board for a most interesting talk which touched on a wide variety of related subjects from the magnitude of our universe to the educational requirements necessary to meet the challenge of our newest frontiers. This most interesting and thought provoking talk was enjoyed by all.

S/L Falls, our Programme Chairman, thanked the speaker on behalf of those present.

Refreshments were served during the most enjoyable social period which followed.

Ottawa

Reported by W/C A. N. le Cheminant

January Meeting

A near capacity audience of over 90 members and guests gathered at the RCAF Gloucester St. Mess to hear an illustrated talk by Mr. R. P. Alex, President of the American Helicopter Society and Head of Component Design for Sikorsky Aircraft. His talk on "Soviet Aviation Today" stemmed from his visit to the USSR as American delegate to the 32nd Conference of the FAI held in Moscow in May 1959. The Chairman, CDR N. A. Smith, asked Mr. R. D. G. O'Donnell of the Programs Committee to introduce the speaker. This he did by enlightening the audience on Mr. Alex's background which made him an observer par excellence of the Russian scene from an aeronautical viewpoint.

That Mr. Alex spoke for close to two hours without any script and displayed over 200 slides has left the writer a task of no mean magnitude to even mention a few highlights.

Starting off with a few general remarks, the slides soon took us straight to the reception of the delegation at the Moscow airport. We were fortunate that in the audience we had Mr. M. Seymour of St. Catharines who was a Canadian delegate to the same conference; he was in company with Mr. Alex a goodly portion of his time in Russia and on the outward and return trips. His presence brought forth the odd confirmatory question by the speaker. The speed of the escalator systems feeding the 200 ft below ground excellent transportation subways of Moscow served to draw attention to their modernness compared with New York. The absence of commercial vehicle traffic during the day improved the traffic situation.

The number of pilots trained and the high standard obtained by the Russian Aero Club were demonstrated by displays which lent emphasis to the motto

for motivation of young people of Models to Gliding to Aircraft. The Moscow club had some 2,000 gliders, 1,000 aircraft and 500 helicopters. Aeroflot, the transport organization, had carried 8 million people in 1958 and expected to increase this to 21 million by 1961. Numbers generally appeared to be quite astronomical but none the less authentic.

Problems too had arisen – corrosion of magnesium and light alloys led the way to vacuum melted and vacuum poured steel castings as means of gaining better strength to weight ratios, and brought to mind that Canadian ventures into steel casting techniques for aircraft purposes had apparently died years ago from lack of interest. Strength and simplicity were leading to increased overhaul times and empirical solutions of the decision to produce an article were paying good rewards. Reduction in helicopter vibration was managed in at least one manner by substituting much stiffer fully hardened gears for our more generally accepted surface hardened variety. A standardized blade construction was also evident.

The rewards to be gained by successful designers were also exemplified by freedom of travel besides medals. Bonus rewards for successful designs were handsomely given not only to the designer but to all staff in proportion to their salaries. These were improving to the point where the margin of superiority of the capitalistic variety was fast disappearing. Elimination of multiple profit requirements would give the Soviet economy a marked advantage. Names like Andrei Tupolev, General Shepilov, Mikail Mil, and the Mil series of helicopters will have new meanings to those who listened and saw.

Mr. R. J. Templin of NRC ably thanked the speaker after a brisk question period that had to be curtailed by reason of the closeness of the witching hour. A few stalwarts continued into the wee hours.

SECTIONS

ASTRONAUTICS

Newsletter No. 1

by Dr. H. J. Luckert

(The Astronautics Section is introducing a series of "Newsletters" and "Astronautics Notes" which will be distributed to all members of the Section. The Newsletters, perhaps in slightly modified form, will be published in the Journal. Except in cases of rather general interest, it is not proposed to publish the Astronautics Notes for the time being. – Sec.)

The Astronautics Section, which came officially into being when the first Executive Committee took office on October 9, 1958, can now look back over a little more than one year of its existence. In this period the membership has increased from 41 to over 90. The start of a new organization is never easy; difficulties have to be overcome and some time must pass before the object and purpose of an "association" such as the Astronautics Section are properly understood, and an efficient and satisfactory method of operation can be established. In these respects great progress has been made.

As stated in the Regulations of the Section, Article 2, "The object of the Section shall be the promotion of the object of the Institute, particularly with regard to astronautics, by appropriate means including:

(a) The provision of facilities for the exchange of information among its members,

(b) The holding of meetings for the presentation and discussion of technical subjects pertaining to astronautics, and

(c) The publication, through the publications of the Institute, of papers, reports, notes and the like, pertaining to astronautics."

In the past year, a number of papers on astronautical subjects have been given at Annual Meetings of the Institute and some Branch meetings have been addressed by speakers on astronautics. All these activities have been reported more or less fully in the Journal, but it is evident that the Journal, serving the whole Institute, cannot devote too much space to the details of the activities of any one Section. Furthermore the membership of the Section is spread across Canada and there are even some members in the USA; many of these are not so fortunate as to belong to the larger Branches where naturally the opportunities for group activity are greatest.

It has been decided to issue these Newsletters, primarily for the benefit of the members of the Section, to summarize the scattered activities of the Section and the plans and programmes for the future. At the present stage it is too early to guarantee a true "periodical" but it is hoped that, as a beginning, the Newsletter can be issued at intervals of about three months.

The present Newsletter will report on the events of the last few months, present some suggestions about procedures and efficient methods of operation, and outline the future plans developed by the Executive Committee.

Formation of Local Groups

According to the Section Regulations (Article 6, Section 4), "where there are in excess of 5 members of the Section who are also members of a particular Branch of the Institute, such members may constitute an Astronautics Group of the said Branch". There is no doubt that the formation of these local specialist Groups is highly desirable wherever possible. However, it is evident that a Group is not effective as a mere list of members; it can only be effective if the members of the Group have a working plan and meet frequently for discussions on topics related to their special field – in this case astronautics. Only so can the interest in the various aspects of astronautics be furthered and widened, and progress made.

First Discussion Evening of the Montreal Group

At present Montreal, Toronto and Ottawa fulfil the requirements for the formation of Astronautics Groups and efforts should be made to constitute Groups in these Branches. A start has already been made in Montreal, where Section members were invited to an informal meeting held on November 5, 1959. The purpose of this first "Discussion Evening" was to set up a Montreal Astronautics Group and to work out procedures for Group meetings. The theme chosen was "Dispersion", and discussion was based on a paper recently presented at the Astronautics Session of the UTIA Symposium in Toronto, October 15, 1959, by Dr. E. Bendor of Canadair's Missiles and Systems Division. About 20 members attended.

As an experiment, to develop the technique, the presentation of the subject was purposely restricted, in order to allow ample time for discussion. The simple presentation of papers at formal meetings, with only short discussion of each, is seldom conducive to complete understanding of the papers by those present. The aim, therefore, was to develop a type of meeting comprising a short lecture on some topic, pointing the basic principles of the problem in a more or less informal and elementary way, followed by a discussion, on which the main emphasis should be placed.

The short lecture at this first meeting of the Montreal Group started from a general definition of Dispersion, discussed the significance of Dispersion and gave some examples, particularly from the field of unguided rockets. A detailed report on the meeting was prepared as an Astronautics Note and distributed to all members of the Section.

It must be realized that these Discussion Evenings have been started as an experiment and their success will depend to a great extent on the response of all participating members. The result can only be appraised after some experience – say at least three meetings. The Montreal Group plans its next Evening in February, with a discussion on Calculation of Trajectories and Orbits. Other topics for following meetings, to give a few examples, will be Gravity, Properties of the Upper Atmosphere, Guidance and Control Problems, etc.

When the Discussion Evening technique has been fully developed, the effective formation of the Group will have been achieved and it is hoped that a fixed schedule of Group meetings can then be established.

Montreal Branch Astronautics Meeting, November 1959

It is a common practice at the larger Branches to devote at least one meeting each season to a lecture on the special field of one of the Sections. In Montreal such a meeting, sponsored by the Astronautics Section, was held on November 18, 1959. The speaker was Dr. M. Baron T. George, Director of the Plans and Program Office of the AVCO Research and Development Division, Wilmington, Mass. Dr. George gave an interesting lecture on re-entry problems, discussed the progress in experimental research, heat shield design methods for ballistic missile nose cones, re-entry from manned space flight, and advanced re-entry vehicles, including studies of re-entry after a photographic reconnaissance on Mars or Venus.

A brief report of this meeting has been published in the December issue of the Journal (Page 422). However a more detailed account of the lecture is being sent to members of the Astronautics Section in the form of an Astronautics Note.

Astronautics Notes

Now a few words about Astronautics Notes which have already been mentioned. Notes of this kind should establish a very useful means of communication between the members of the Section, and all Groups and individual members are encouraged to report on events, lectures or studies which come to their attention and which would be of particular interest to the other members of the Section. To quote a suggestion by the Secretary of the Institute: How about a friendly competition in the production of Astronautics Notes from various Groups? This would be of utmost benefit to the whole Section and it is hoped that the first two Notes which have now been issued will give a start to a series of increasing usefulness.

Dr. de Vaucouleurs to Address Montreal and Ottawa

The Executive Committee succeeded in obtaining the agreement of Dr. G. H. de Vaucouleurs, the noted French scientist now at Harvard Observatory, Cambridge, Mass., to address Astronautics Section meetings in Montreal and Ottawa. Dr. de Vaucouleurs is an astronomer and astrophysicist and an outstanding expert on the planets Venus and Mars. Last summer, at the August dinner meeting of the Holloman Section of the American Rocket Society, he gave a lecture on the latest information yielded by modern science concerning Venus. A summary of his address was given in the Holloman Monthly News Bulletin, Vol. 3, No. 10 (August 1959).

Dr. de Vaucouleurs will address a dinner meeting in Montreal on the 23rd February and will be in Ottawa the following day.

Future Plans and Activities of the Astronautics Section

In addition to the local Branch activities, the Astronautics Section is co-operating with the National Programmes Committee in several ways. The Section will sponsor a session at the Annual General Meeting, the tentative title of which is "Man in Space". In addition to this, plans are being made to sponsor a Symposium on the Canadian High Altitude Research Programme this coming Fall. More information concerning These Section activities will be published in future Newsletters.

Concluding Remarks

This first Newsletter is a modest start to what it is hoped will become a useful medium for communication of our specialist membership, the Astronautics Section, with the aim of concentrating all our efforts towards progress in astronautics within the framework of the Canadian Aeronautical Institute.

COMING EVENTS

CAI

19th and 20th February—*Mid-season Meeting*, Kingsway Motor Hotel, Edmonton

BRANCHES

Vancouver

16th March — *Why the F-104?* A/C W. W. Bean.

30th April—Annual General Meeting.

Montreal

16th March — 7.00 p.m. Airlines Cafeteria. *First Year's Operational Experience with the Big Jets*, Mr. P. Kearvall, I.A.T.A.

18th April—Visit to the new TCA overhaul base at Dorval. (Joint with SAE)

UNIVERSITIES

McGill – A series of lectures on flight will be held in the Faculty of Engineering, Thursdays at 7.00 pm, Room 204, McConnell Engineering Building. Admission is by ticket only. Tickets may be obtained from Miss M. Rosner, Secretary, Dept. of Mechanical Engineering, McGill University, Montreal 2, P.Q.

The outstanding lectures are as follows:

18th February—*Polar and Mid-Latitude Navigation: Present and Future*, W/C K. R. Greenaway, RCAF.

25th February – *Flight Propulsion*, Dean D. L. Mordell, McGill University.

3rd March—*The Evolution of Aircraft Structures*, A. R. Edis, McGill University.

10th March—*Flight into Space*, W. F. Campbell, NRC.

SUSTAINING MEMBERS

Field Aviation Company Limited of Oshawa and Calgary has announced plans for construction of a $1,000,000 hangar at Toronto's Malton airport to meet the needs of business aircraft owners in the Toronto area.

Construction of the 74,000 sq ft hangar was started before the end of 1959. It will be built of pre-stressed concrete with new type power-operated hangar doors. It will be large enough to accommodate 20 medium-sized multi-engine aircraft or a Lockheed Super Constellation airliner with still some space left over.

As well as storage space for aircraft there will be a complete business aircraft service centre comprising overhaul facilities including radio, electronics and other service shops. For pilots and passengers there will be lounges, offices and flight planning facilities.

The Malton facility will, of course, include Field's Canadian Beech aircraft sales and service centre.

This is Field's second business aviation centre in Canada. A similar hangar was opened in Calgary in the spring of 1959.

The opening of the Malton establishment will mean a gradual move away from Oshawa to Malton of the Field overhaul operations and aircraft parts and supply services. However the Oshawa facility will not be closed down.

To aircraft operators in the Toronto area this new venture should mean an end to the acute hangar shortage problems. This is most noticeable in wintertime when hours of delay are often caused by aircraft having been left in the open.

Bristol Aero-Industries Limited have announced some interesting technical notes on ducted fan engines, in particular on the BE 58 (Figure 1) developed by the associated company, Bristol-Siddeley Engines Limited in England. These notes are summarized below.

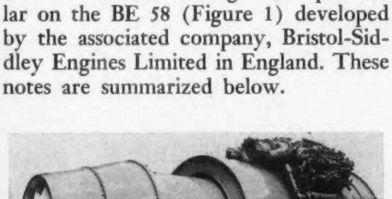


Figure 1
Bristol-Siddeley BE 58 ducted fan engine

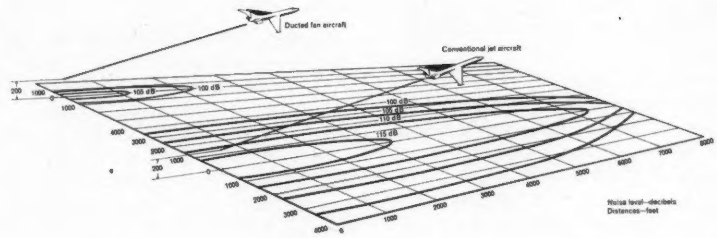


Figure 2
Ducted fan vs turbojet or bypass engine (noise)

Ducted fan engines of this range have a cold-flow ratio of between 1.5 and 2.0; that is to say, the amount of air delivered by the fan through the duct is between one and a half times and twice that which passes through the combustion section of the engine. This characteristic distinguishes the true ducted fan engine, whether manufactured in Great Britain or the United States, from the by-pass engine which has a cold-flow ratio of round about 0.5.

In fact, the by-pass engine of the known type, as installed in certain long-range subsonic jet airliners can be grouped with the straight turbojet for practical purposes. Although a step in the right direction, the by-pass engine with its low cold-flow ratio, or by-pass ratio, and with the high maximum cycle temperature used, does not differ to any great extent from the normal turbojet in respect to noise level, specific thrust and fuel economy.

On the subject of engine noise, an authoritative paper appeared in the September *Journal of the Royal Aeronautical Society* entitled "Some Aspects of Engine Noise" by P. Lloyd, Deputy Director of the National Gas Turbine Establishment. In this paper the writer, after stating that the power put out by a jet in the form of noise is proportional to about the eighth power of the jet velocity, compares the noise rating of a number of engines. The author shows a graph of engine noise ratings and indicates that military jet engines and supersonic civil engines are likely to have jet velocities of 2,300 ft/sec for which the corresponding noise rating is 122 decibels. Subsonic straight turbojet engines, designed for a lower fuel consumption, have jet velocities at takeoff in the range of 1,900-2,100 ft/sec, the corresponding noise rating being between 117 and 119 decibels. Existing by-pass engines, which have a cold-flow ratio of the order of 0.5, have a jet velocity of about 1,700-1,800 ft/sec and a corresponding noise rating of 114-115 decibels.

The true ducted fan engines, however, have a jet velocity of the order of 1,200 ft/sec for which the corresponding noise rating is only 103 decibels. Thus it is true to say that the noise level of Bristol-Siddeley ducted fans is some 10 decibels lower than that of the best existing turbojet or by-pass engine, and some 15 decibels lower than that of the average civil jet engine (see Figure 2).

Another remark made in the same paper is of interest, namely that: "It does seem clear that for subsonic flight it is intrinsically better to achieve whatever noise level is required by using engines of low jet velocity rather than by taking simpler jet engines and suppressing their noises at the cost of performance penalties. Certainly this conclusion is fully supported by the only detailed study of the problem which has been published, namely that by Pearson and Fitzgerald[a]. They consider the case of a short-to-medium range airliner and show that whereas 10 decibel noise reduction by a noise suppressor nozzle would add 6% to direct operating cost, the same reduction obtained by means of special engines would give a similar *reduction* in direct operating cost. For long-range aircraft, the case for using special jet engines would be reinforced and the optimum by-pass ratio would be greater".

[a]Pearson, H., and Fitzgerald, R. M.—*Some Considerations Affecting the Design of Engines for Short-to-Medium Range Airliners,* THIRD EUROPEAN AERONAUTICAL CONGRESS, 1958.

The ducted fan engine inherently has a high mass flow of air displaced by the fan at relatively low velocity; this has the disadvantage of producing a low specific thrust, but this is the inevitable accompaniment of the high propulsive efficiency which results in the very low specific fuel consumption which is the highly attractive feature of this type of engine.

These points are illustrated in Figure 3, which is taken from the paper by Lloyd referred to above. The figure clearly shows the two effects resulting from the adoption of the ducted fan (or the by-pass engine which is a special case of the ducted fan) in place of the straight turbojet. The specific thrust in terms of lb thrust/lb of airflow/sec is reduced, and the specific fuel consumption in lb of fuel/hr/lb of thrust is also lowered. The greater the cold-flow ratio of the engine, the more are these two reduced.

The graph is compiled for a hypothetical family of engines cruising at a flight speed of 500 knots at 36,000 ft. A pressure ratio of 12:1 is assumed together with the following data:

Isentropic efficiency of the fan	86%
Polytropic efficiency of the high pressure compressor	89%
Combustion efficiency	98%
Combustion pressure loss	5%
Efficiency of the turbines	88%

No thermodynamic advantage was assumed from mixing of the exhaust streams; the data is based on engine thrust without corrections for external drag.

It will be seen that for a turbine entry temperature of 1,100°K the by-pass engine having a cold-flow ratio of 0.6 has a specific thrust of 32 lb/lb airflow/sec and a specific fuel consumption of 0.91 lb/lb/hr, while the ducted fan engine with a cold-flow ratio of 2.0 has a specific thrust of just over 20 lb/lb airflow/sec and a specific fuel consumption of 0.84 lb/lb/hr at the same turbine entry temperature.

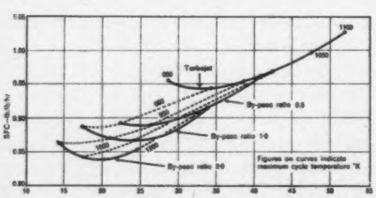


Figure 3
Ducted fan vs straight turbojet (fuel consumption)

In spite of the inherently low specific thrust of the ducted fan engine, two factors result in the Bristol-Siddeley range of engines, including the BE 58 shown at Farnborough, having a thrust: weight ratio as good as, or better than, that of current turbojets. These factors are the advanced detail design of the engine, and the fact that the specific thrust is based on the total air flow, approximately three-quarters of which, in the case of the BE 58, does not pass through the compressor, combustion equipment and turbine, but merely requires a simple duct (see Figure 4). The thrust of the BE 58 is 14,500 lb for a weight of 2,600 lb – giving a thrust: weight ratio of 5.6:1. This is almost as high as that of the best turbojet of optimum size such as the Bristol-Siddeley Orpheus, and it is substantially better than that of present-day turbojet engines in the same thrust range as the BE 58.

The reduction of specific fuel consumption from 0.91 lb/lb/hr for the by-pass engine to 0.84 lb/lb/hr for the ducted fan represents a very significant improvement in operating economy. If the external drag of the nacelle for the ducted fan is taken into account, the improvement will be slightly reduced. Calculations show that the effect of the larger nacelle of the ducted fan reduces the gain in specific fuel consumption compared with the straight turbojet from some 12.5% to about 10%. This depends, however, on what compromise is effected in nacelle shape between cruising and takeoff requirements. Lloyd, in the paper referred to, concludes that, taking this factor into account, the improvement in specific fuel consumption offered by a ducted fan having the high cold-flow ratio of 2:1 falls to 7% compared with the straight turbojet. It may be pointed out, however, that the generalized curves given by Lloyd are

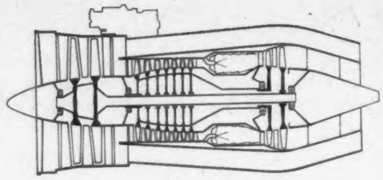


Figure 4
Layout diagram

somewhat pessimistic in respect to the Bristol-Siddeley BE 58, which has a specific fuel consumption cruising at 36,000 ft of 0.80 lb/lb/hr.

Computing Devices of Canada Limited have announced that they have been awarded a contract to develop and manufacture an advanced automatic dead reckoning navigation system for the new RCAF CF-104G fighters.

This system will be known as the Position and Homing Indicator Mk. 5 (PHI 5), and it will be similar to that already in production for the West German Air Force. The quantity will be in excess of 200 units, with a total value of about $4,000,000.

The heart of the PHI 5 is a miniature analog computer which continuously computes the course and distance to any one of twelve pre-selected destinations. The PHI works on the principle of dead reckoning, in effect computing where it is by remembering where it started and keeping track of all courses and speeds flown. The pilot has a choice of twelve targets or destinations on a rotary switch like a television channel selector. Selecting any one of these causes the pilot's indicator to show him the heading to fly to reach that destination, and the distance to go in nautical miles.

The pilot's indicator consists of a compass card, pointer, and mileage counter. Turning the aircraft so that the pointer is vertical means that the aircraft is flying directly to the selected destination. The counter indicates the distance to go and when it reads zero the aircraft is over the destination. All such factors as wind speed and direction and magnetic variation are automatically allowed for by the computer.

Total weight of the PHI is less than 25 pounds.

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